Conceptual Framework, Monitoring Components And Implementation Of A NPS Long-Term Ecological Monitoring Program

Prairie Cluster Prototype Program Status Report

by

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Prairie Cluster Prototype LTEM Program
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Overview of NPS Prototype Long-Term Ecological Monitoring Program

In the early 1990s, the National Park Service initiated a series of prototype Long-Term Ecological Monitoring (LTEM) programs to gain experience with natural resource monitoring. The first four prototype monitoring programs (CHIS, DENA, GRSM, and SHEN) were funded in 1992, generally chosen because considerable design work had already been accomplished. In 1993 the Washington office issued a Call for Proposals to competitively select seven additional prototype monitoring programs. The goal was to maximize the experience gained from the pilot programs by representing the major biogeographic regions and a range of park sizes. The Prairie Cluster prototype was one of seven programs selected through this competition with initial funding provided in FY 1994. It was the first prototype to address the problem of designing monitoring for a group of small parks.

In FY 2000, through the Natural Resource Challenge, the National Park Service launched the Core Park Vital Signs Monitoring Program. This effort will initiate monitoring of significant natural resources in all 270 park units by FY 2004. Parks are being organized into 32 geography-based networks in order to maximize monitoring efficiency. While funding is currently insufficient to implement comprehensive natural resource monitoring, the network approach will provide consistent funding to initiate core monitoring programs in all parks.

The Servicewide I&M leadership has recently decided that the seven funded prototype LTEM programs will continue to be funded at current levels and will serve as "centers of excellence", maintaining more in-depth monitoring efforts and continuing research and design work. The prototype programs will benefit the developing networks by 1) serving as training and mentoring sites, 2) providing specialized expertise regarding data management and analysis, and 3) producing exportable monitoring protocols, including ecoregion-specific methodologies and technical guidance (e.g. sampling design, power analysis). Through the prototype program, the Service now has a small system of long-term, intensive monitoring sites, akin to other nationwide monitoring networks. By maintaining the research and development efforts of the prototypes, we will be better equipped to build a Servicewide natural resource monitoring program.

This document will serve as an update to the original Prairie Cluster proposal. The document is organized in three parts. Part 1, Section A introduces the six parks of the Prairie Cluster, describing their natural resources and resource management issues, and then concludes by summarizing the original program design. Part 1, Section B develops models of terrestrial and aquatic prairie ecosystems and considers their implications for monitoring prairie resources. Part 1, Section C presents a recent management review of monitoring priorities and proposes the addition of Tallgrass Prairie National Preserve to the Prairie Cluster. Part 2 includes a brief summary of each current and proposed monitoring project. Finally, Part 3 provides a brief history of the program, outlines its current organization, staffing and budget, and summarizes data management efforts.

PART 1. PROGRAM DEVELOPMENT

A. Introduction to the Prairie Cluster Prototype LTEM Program

1. The parks, their natural resources and management issues

North American prairie once extended across the mid-continent region from Canada to Texas and from the Rocky Mountains to the Appalachian forest. The vast landscape was nearly continuous grassland, transitioning gradually from shortgrass steppe in the west to tallgrass prairie and savanna in the east. Today, Great Plains grasslands are fundamentally altered by the conversion of prairie to cropland and pasture, the removal or disappearance of native ungulates, drainage of wetlands, and an increase in woody vegetation through plantings and fire suppression. Estimates of the loss of native prairie range between 80% and 99.9%. Fragmentation of the tallgrass prairie ecosystem has left our national parks with a unique challenge to help preserve remnants of this nearly vanished habitat.

The six parks of the Prairie Cluster are relatively small, historic parks. Until recently, the native prairie and savanna vegetation of these parks has primarily been treated as a backdrop for interpreting each park's cultural significance. Restoration of prairie and savanna communities was undertaken mainly to recreate historic landscapes. More recently, the contribution of these remnant grasslands to regional biodiversity has been recognized. The most significant natural resources and natural resource management issues of the Prairie Cluster parks are summarized in Tables 1 and 2, respectively.

While each park has a unique mission and represents a distinctive component of regional biotic diversity, these parks share many natural resource management issues. All include high-quality prairie remnants, sites requiring complete restoration, and a continuum of resource conditions between these two extremes. The two most eastern parks, Wilson's Creek NB and Effigy Mounds NM are also managing oak savanna remnants. Restoring prairie/savanna vegetation to disturbed sites and managing grassland communities with prescribed fire are common resource management priorities.

The small size of the parks makes them particularly susceptible to external threats. Agricultural, residential and industrial development are prominent land uses adjacent to these parks. Because small parks are often inadequately buffered against edge effects, invasion by exotic plant species is a pervasive problem. Water pollution may be the most urgent external threat. Because the parks are small, their springs, creeks and ground water are particularly vulnerable to external pollution sources, and cannot be insulated by buffer zones or resource management inside the parks. Most of the parks must also protect unique habitats and manage state or federally listed, rare and endangered species. Appendix A includes a more detailed description of the natural resources and resource management issues of each park.

Table 1. Most significant natural resources of Prairie Cluster LTEM parks.

MOST SIGNIFICANT NATURAL RESOURCES	
Native tallgrass & mixed grass prairie	Grassland birds
Restored tallgrass & mixed grass prairie	Grassland herpetofauna
Oak savanna/woodland	T&E Species Missouri bladderpod* Western prairie fringed orchid* Topeka shiner* Gray bat* Black-tailed prairie dog State-listed rare species
Prairie streams	
Riparian corridors	
Springs, caves	
Unique habitats (goat prairies, glades, rock outcrops, gravel washes, eroding siltstone slopes, etc.)	

*Federally listed T&E Species

Table 2. Most significant natural resource management issues of Prairie Cluster LTEM parks.

MOST SIGNIFICANT RESOURCE MANAGEMENT ISSUES
• Managing remnant prairies and savannas with prescribed fire
• Restoring prairie/savanna vegetation to recreate historic landscapes
• Controlling invasive exotic species
• Managing T&E species habitats to maintain stable populations
• Maintaining integrity of unique habitats and their associated flora/fauna
• Providing adequate habitat for grassland bird and herpetofauna communities
• Preventing negative impacts associated with deer overabundance
• Declining stream water quality associated with external development and land use
• Controlling visitor use to minimize resource impacts

2. Original Program Design

The original proposal for the Prairie Cluster LTEM Program was written in 1993 with Gary Willson (USGS/BRD) and Lisa Thomas (NPS) as primary authors and Terrence Boyle (Aquatic Ecologist, USGS/BRD), Victoria Grant (NPS) and John Harrington (Restoration Ecologist, University of Wisconsin/Madison) as contributors. Ron Hiebert, former NPS MWR Chief Scientist, and Steve Cinnamon, MWR Natural Resource Specialist, also provided advice. The contributors brought a range of resource expertise to the planning table and were well acquainted with the parks and their resource issues. However, the group did not use a formal planning process, or convene panels of specialists to guide them in developing a monitoring plan. The contributors relied instead on a thorough review of park Resource Management Plans, an assessment of recent inventories, and comment and discussion from park resource managers and superintendents. Core indicators were selected to assess the condition of the park's most significant natural resources and capture changes resulting from anticipated threats and management actions.

The monitoring proposal included an assessment of the completeness of existing inventories for the Prairie Cluster parks, identifying the completion of vertebrate (particularly bird), insect and lichen inventories as priorities. It also recognized the lack of baseline GIS imagery for the parks and proposed acquiring and developing the necessary baseline spatial imagery. The proposal defined a central ecological question to guide monitoring activities and outlined four key strategies for long-term success (Table 3).

Table 3. Original monitoring strategy for the Prairie Cluster Prototype LTEM Program.

Central Monitoring Question:

To what extent are the species, communities, and ecological processes of small remnant and restored prairies sustainable?

Original Monitoring Strategy:

Limited Scope. In order to sustain a monitoring program within the context of small parks, monitoring must be limited in extent, precise in focus, and targeted toward the most significant issues and resources. The program will monitor the impacts of external development and land use, and assess the effectiveness of resource management practices, using a few key indicators of ecosystem integrity.

Ecological Framework. The monitoring themes revolve around a question that is central to management decisions and also relevant to the emerging disciplines of restoration ecology and conservation biology. Indicators were selected to include monitoring at several ecological levels. Population-level monitoring will be used for rare species. Community-level indicators were chosen to assess the integrity of prairie vegetation, to determine if prairie remnants are supporting diverse faunal assemblages, and to assess stream health using macroinvertebrates.

Standards. Measurable monitoring objectives will be developed to: 1) identify and assess impact-induced changes before large-scale damage has occurred, and 2) evaluate and adjust management responses. Monitoring results will be accessible and fully integrated into park decision making.

Partnerships. To successfully maintain long-term monitoring in small parks, inherent problems of understaffing, high turnover, and poor institutional memory must be addressed. Partnerships with local colleges, universities, and other agencies will be emphasized to bridge these gaps and maintain continuity and quality control.

A two-phase monitoring design was originally proposed with high priority monitoring projects scheduled for initiation in the first years of the design phase, and moderate priorities to follow in later years. During visits to the CHIS and SHEN prototype programs in the summer and fall of 1994, their program managers expressed concern that staff time was easily over-committed to data collection, with too little time remaining for data management, analysis and interpretation. We decided to heed the voice of experience and stay focused on monitoring a few things well. Consequently, the design of the program was modified to concentrate on the core Phase I issues. Table 4 lists the monitoring components of the Prairie Cluster LTEM Program.

Table 4. Monitoring components of the Prairie Cluster Prototype LTEM Program.

Terrestrial and Aquatic Ecosystems

- ***Landscape Monitoring***
  - Adjacent land use

Terrestrial Ecosystem

- ***Community Monitoring***
  - Plant communities
  - Grassland birds[1]
  - Grassland butterflies[1]
- ***Population Monitoring***
  - State-listed T&E plants
  - Missouri bladderpod (*Lesquerella filiformis*)[*]
  - Western prairie fringed orchid (*Platanthera praeclara*) [*]
  - Black-tailed prairie dog (*Cynomis ludovicianus*)
- ***Environmental Monitoring***
  - Local weather (related to *L. filiformis* and *P. praeclara* dynamics)[2]

Aquatic Ecosystem

- ***Community Monitoring***
  - Macroinvertebrates as indicators of stream health
- ***Population Monitoring***
  - Topeka shiner (*Notropis topeka*) [3 *]

[*] Federally threatened or endangered species
[1] Phase II (moderate priority) in original proposal
[2] Not included in original proposal
[3] No park occurrence record at time of original proposal

As the design phase continued, a series of monitoring questions was posed to examine how external threats and resource actions might affect the core indicators (Figure 1). For each monitoring question, we then considered how core datasets might be used with ancillary environmental data and management records to answer the underlying management questions (Table 5). Finally we considered how monitoring information from several monitoring projects could provide management feedback concerning the overall integrity of prairie ecosystems. Figure 2 illustrates the integration of feedback from several monitoring projects to assess the health of prairie vegetation.

Figure 1. Key ecosystem threats and management actions affecting indicators of ecosystem health. The selected indicators provide a balanced approach that includes landscape, community and population level monitoring.

Are prairie remnants sustainable within small parks?

Threats

Landscape

How is external land use changing?

Are land-use changes affecting prairie remnants?

Community

Is the water quality of prairie streams declining?

Where are are invasive exotics distributed within and adjacent to the park?

Population

Are rare species re-colonization sources disappearing?

Indicators of Ecosystem Health

Is the proximity or size of nearby prairie remnants changing?

Do prairie streams support diverse macroinvertebrate communities?

Do small prairie remnants support diverse native plant communities?

Do small prairie remnants support diverse butterfly and bird communities?

Are rare species populations stable?

Resource Actions

How is prescribed fire affecting prairie plant communities?

Are restoration methods working?

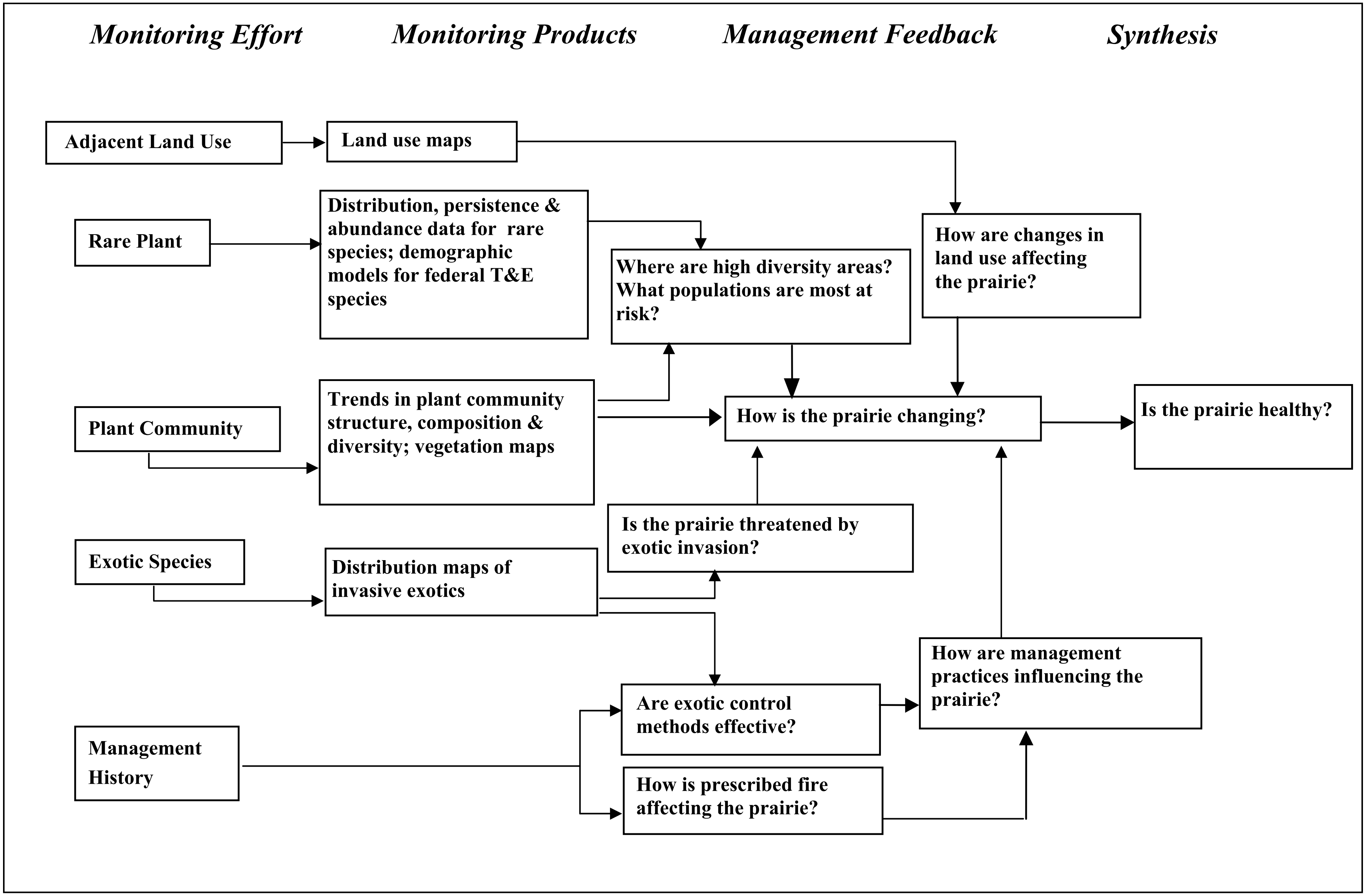
Is rare species habitat protection & restoration working?

Are exotic control efforts effective?

Table 5. Proposed approach to address each monitoring question.

Monitoring Question	*Monitoring Tools/Approach*
Threats	
How is external land use changing?	Historic and current aerial photography to document urban development, changes in agricultural use, loss of adjacent natural areas.
How are invasive exotics distributed within the park?	Aerial photography and field surveys to record changes in distribution of invasive exotics.
Is the water quality of prairie streams declining?	Biomonitoring, using macroinvertebrates as indicators of overall stream health.
Resource Actions	
Are restoration methods working?	Comparison of structure, composition and diversity of restored plant communities to native reference sites.
How is prescribed fire affecting prairie communities?	Structure, composition and diversity of plant communities within permanent sample sites. Diversity and abundance of birds and butterflies.
Are exotic control efforts effective?	Frequency and cover estimates of exotics within plant community sample sites.
Is rare habitat protection & restoration working?	Distribution, persistence and abundance monitoring of rare species populations
Indicators of Ecosystem Health	
Do small prairie remnants support diverse native plant communities?	Structure, composition and diversity of plant communities within permanent sample sites.
Do small prairie remnants support diverse butterfly and bird communities?	Butterfly diversity and relative abundance within permanent sample sites. Bird diversity and relative abundance using point counts.
Are rare plant populations stable?	Distribution, population persistence, and/or abundance estimates. Demographic monitoring of federally listed species.

Figure 2. Flowchart illustrating synthesis of feedback from several monitorng projects to assess prairie vegetation health.



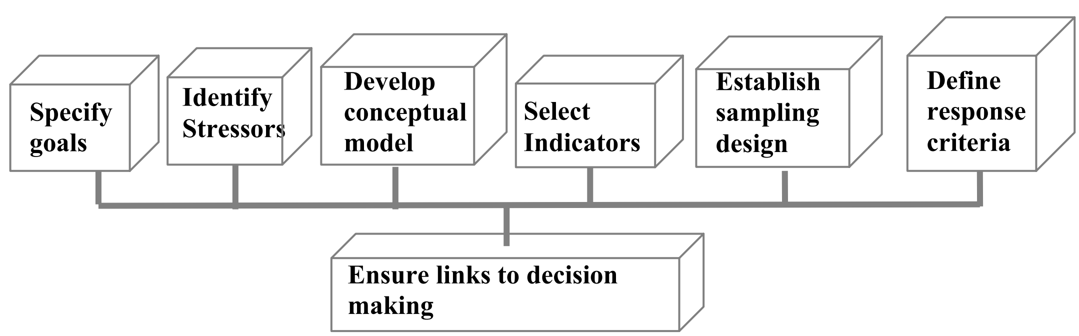
B. An ecological framework for monitoring within prairie ecosystems

We sought to review the original design of the Prairie Cluster LTEM Program within an ecological context for two reasons. First, we want to ensure that we are monitoring the right components to detect change in the ecological integrity of the system. Karr (1991) defines ecological integrity as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region. Secondly, an understanding of the defining characteristics of functioning prairie ecosystems may help us differentiate between normal ecosystem variability, and negative trends in resource condition that result from external stresses. Models may also provide direction for identifying limiting environmental factors that could be monitored in conjunction with biotic components of the system.

Monitoring data are intended to detect long-term environmental change, provide insights into the ecological consequences of change and help decision-makers determine if observed change indicates that a correction to management practices is needed (Noon et al. 1999). Detecting meaningful change is complex because natural systems are inherently dynamic and spatially heterogeneous. Changes in time may not be the result of human-induced effects, but rather the result of intrinsic variability of natural systems (e.g. stochastic or cyclic variation, succession). Generally, extrinsic drivers of change arising from human impacts are of greater interest to environmental monitoring programs than intrinsic factors. One goal of a monitoring program is to filter out the effects of expected intrinsic variation from the additive, human-induced patterns of change (Noon et al. 1999).

We adopted a process developed by Noon et al. (1999) to guide us in reviewing our monitoring program within an ecological context (Figure 3). The first step is to clearly state monitoring goals and objectives, describing how periodic information about the status of the resources is needed for informed decision making. The next steps involve establishing the relationship between those factors that may compromise the management goals and their ecological expression. Noon et al. (1999) advise using a conceptual model to help anticipate how a system will respond to external stresses.

Figure 3. Steps in the design of a monitoring program (from Noon et al. 1999).



1. Specify goals and objectives

NPS 75 defined natural resource monitoring as "long-term systematic repetition of a specific resource survey and the analysis of those data to predict or detect natural and human-induced changes in resource condition, and to determine if natural resource condition objectives are being achieved." Based on that definition, we developed five goals of the PC-LTEM Program.

Goals of Prairie Cluster LTEM Program
• Determine status and trends of the health of park ecosystems
• Establish normal limits of variation in key park resources
• Provide early warning of resource decline
• Evaluate the effectiveness of resource management practices
• Develop a predictive understanding of environmental change

A review of the successes and failures of previous long-term monitoring efforts has led us to further describe five key characteristics of an effective monitoring program. The specific objectives of each monitoring project are provided in Part 2.

An Effective Monitoring Program Must:
• Be relevant to current management issues & resource threats
• Anticipate future issues and threats to park ecosystems
• Be scientifically credible
• Generate accessible, high-quality data
• Feed back into decision-making with timely, relevant data

2. Identify stressors and develop conceptual ecosystem models

Conceptual models depicting key structural components, and system drivers assist us in thinking about the context and scope of the processes that effect ecological integrity (Karr 1991). They also provide a heuristic device to expand our consideration across traditional discipline boundaries (Allen and Hoekstra 1992). Clear, simple models facilitate communication 1) between scientists from different disciplines, 2) between researchers and managers, and 3) between managers and the public. We have taken a strategic modeling approach (May 1973) as a way of formalizing generalizations about prairie ecosystems.

Our understanding of prairie ecology has been advanced by several significant research syntheses -- Weaver's classic description of decades of research concerning the response of prairie species and communities to cattle grazing and drought during the 1930's and 1950's (Weaver 1954; 1968); Risser's summation of the International Biological Program studies at the Osage site in northeastern Oklahoma (1981); and the synthesis of twenty years of research from the Konza Prairie Long-Term Ecological Research Program (Knapp et al. 1998). Other recent volumes devoted to prairie ecology include discussion of the role of fire in tallgrass prairie (Collins and Wallace 1990), conservation and management of prairie ecosystems (Joern and Keeler 1995), and the ecology and conservation of Great Plains vertebrates (Knopf and Samson 1996). Various authors have reviewed the literature, summarizing the key roles of climate, fire and grazing in prairie ecosystems (Risser 1981; Anderson 1982; Singh et al. 1983; Axelrod 1985). The following descriptions are derived from several recent overviews of terrestrial (Anderson 1990; Risser 1990; Bragg 1995; Knopf and Samson 1996; Knapp and Seasteadt 1998) and aquatic (Gray and Dodd 1998; Gray et al. 1998; Fausch and Bestgen 1996) prairie ecosystems. Natural drivers and their effects are summarized in Tables 6 and 7; conceptual models of the core biotic and abiotic components are presented in Figures 4 and 5.

Natural drivers – terrestrial prairie ecosystem

Climate: Temperate grasslands worldwide are characterized by climates with periodic drought that permit the vegetation to dry, by periodic fires, and by landscapes that are level to gently rolling, which allows fires to spread across extensive areas (Sauer 1950). The central grasslands of North America occupy an area resembling a broad triangle, with its base running along the foothills of the Rocky Mountains, and its apex extending as far east as Indiana, with scattered prairie outliers in Michigan, Kentucky and Ohio (Risser 1981). The eastern sector of this grassland region, the prairie peninsula (Transeau 1935), has historically fluctuated between a climate capable of supporting grassland and one supporting forest. Borchert (1950) summarized the common climatic attributes of North American prairie as 1) low winter snow and rainfall, 2) high probabilities of large rainfall deficits in summer, 3) fewer days of rainfall compared to forested areas to the north, south and east, 4) low summer cloud cover, 5) low summer relative humidity, 6) large positive departures from average temperature, 7) frequent hot, dry winds in summer; and 8) frequent large departures from average climatic conditions. Transeau (1935) emphasized that to understand the distribution of grassland in this region, the extremes of climate must be considered, and not the average.

Fire: Fire occurs in a wide variety of plant communities, but is particularly important in temperate grasslands because without fire, most grasslands would ultimately succeed to forests or shrublands (Sauer 1950). North American prairie fires historically occurred in all months of the year, but fuel conditions and weather patterns lead to peak fire probabilities in July/August and secondarily during late spring (Bragg 1982). American Indians frequently ignited fires to drive or attract game (Pyne 1982; Higgins 1986). In mixed grass prairies, both dormant-season and growing-season burns generally decrease total plant production, while in tallgrass prairie, mid- to late-spring burning generally increases overall productivity (Bragg 1995). The patchy distribution of burned and unburned areas affects grazing patterns, attracting bison and other ungulates to the greater productivity and nutritive quality of forage following fire. The overall effect of grazing would therefore be concentrated in the most recently burned units of the landscape (Risser 1990).

Fire results in substantial losses of nitrogen through volatilization, with perhaps twice as much nitrogen lost in a single fire as enters the system yearly in rainfall or by nitrogen-fixing organisms (Seastedt 1988; Ojima et al. 1990; Hobbs et al. 1991). The removal of vegetation and plant surface litter also results in an exposed, soil surface that is warmer and drier than that of unburned prairie. Losses of nitrogen in a fire, followed by losses of water due to increased surface evaporation result in both of these resources becoming less available. With enhanced plant growth, available nitrogen is locked away in plant tissue, while higher photosynthetic rates place strong demands on soil water. Plants respond to nitrogen and water limitations by allocating more photosynthate to roots. This input of new roots to prairie soil has been critical to the accumulation of soil organic matter and humus (Seastedt 1995).

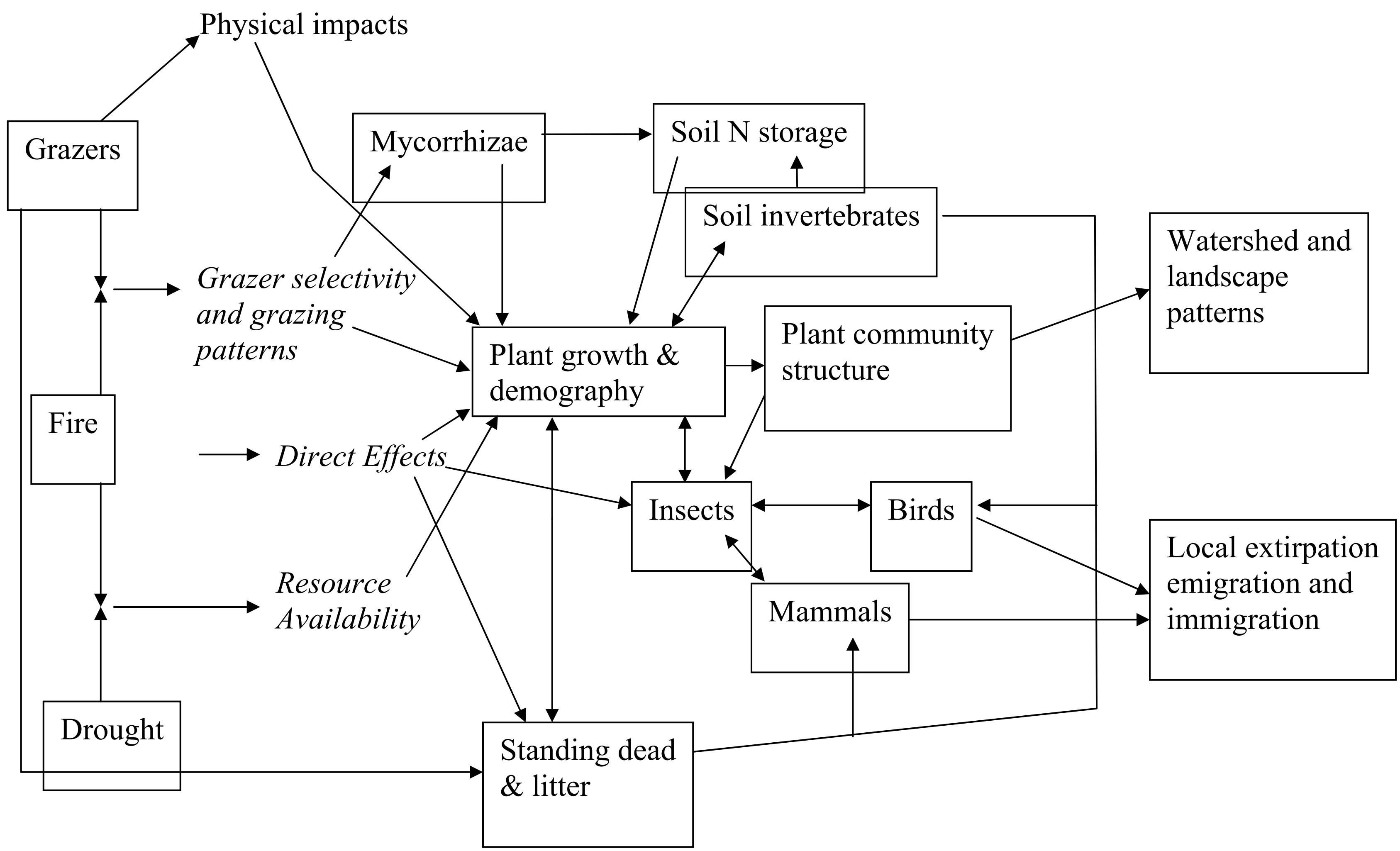
Grazers: Grasslands generally support large numbers of herbivores (Detling 1988). Worldwide, native large mammalian herbivores and cattle remove, on average, 30 to 40% of the aboveground net primary production (ANPP) in grasslands, while insects remove another 5 to 15%. Belowground invertebrate consumers, primarily nematodes, consume another 6 to 40% of the belowground net primary production. While dominant tallgrass prairie species such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*) and Indian grass (*Sorghastrum nutans*) decrease under regimes of prolonged grazing, dominant shortgrass species such as blue grama (*Bouteloua gracilis*), side-oats grama (*Bouteloua curtipendula*) and buffalograss (*Buchloe dactyloides*) increase (Weaver 1954). In the tallgrass prairie, the behavior of grazing animals promotes among-site heterogeneity of vegetation, especially in conjunction with periodic fire (Glenn et al. 1992). In shortgrass prairie, heavy grazing promotes homogeneity of the landscape and light grazing pressure results in enhanced heterogeneity (Larson 1941; Milchunas et al. 1988). Heterogeneity within shortgrass landscapes historically was fostered by the nomadic nature of large herds of bison.

Ungulate grazers increase nitrogen cycling rates in grasslands and are likely to affect export rates as well (Blair et al. 1998). Chronic over-grazing may result in a loss of root mass, as plants respond to herbivory by using root reserves to produce new foliage, rather than sending photosynthate to the root system to find new sources of N and water. The short-term effect of chronic grazing is therefore a more rapid nitrogen cycle, which allows a diminished root mass to provide sufficient nitrogen to maintain foliage production. In the western portions of the prairie, this system may prevail, with the dominant species well adapted to grazing. In the more easterly grasslands, the tendency for the dominant grasses to be outcompeted with nitrogen enrichment suggests that chronic grazing was not the rule (Seastedt 1995). Infrequent grazing may function similarly to infrequent fire, causing a transient pulse of productivity in response to increased availability of nitrogen, water and light.

Table 6. Primary natural drivers and their effects on terrestrial prairie ecosystems.

TERRESTRIAL PRAIRIE ECOSYSTEM -- NATURAL DRIVERS		
Driver	***Resource***	***Effect***
CLIMATE		
Periodic drought	Plant communities	Mortality of trees/shrubs; reduced, patchy vegetative cover; reduced seed production; shifts in species composition
FIRE	Plant communities	Prevention of woody species establishment; increased productivity and seed production (tallgrass prairie); dominance of C_4 grasses (spring fire). Varied seasonality and fire frequency resulted in increased landscape heterogeneity.
	Soils	Loss of nitrogen through volatilization; water loss through surface evaporation; increased root production
	Bison	Foraging patterns follow recently burned areas
GRAZERS		
Bison	Plant communities	Reduced C_4 grass dominance due to selective grazing; increased heterogeneity & species diversity associated with grazing patches, wallows; moderates fire effects by decreasing C_4 grass dominance
	Soils	Consumption of ANPP and redistribution of N in urea and feces moderates fire-regulated N loss through volatilization
PRAIRIE GRASSES & SOIL BIOTA	Soils	High organic matter & nutrient retention; high below-ground productivity, low nitrogen availability, high moisture holding capacity

Figure 4. Relationships between core abiotic and biotic components of terrestrial prairie ecosystems. Arrows indicate known and hypothesized interactions among components. ***Modified from Hartnett and Fay (1998).***



Natural drivers -- aquatic/riparian ecosystem

Climate: Prairie streams are characterized by variable flow regimes (Jewell 1927; Matthews 1988). Low-order streams alternate between stable flows during spring and early summer and intermittent flow to dry conditions during late summer and winter. Scouring floods may interrupt stream flow at any time, but are most prevalent in association with spring and summer storms (Gray et al. 1998).

Many first- and second-order streams in prairies occur in areas without a tree canopy. The extreme variability in streamflow and the lack of woody vegetation lead to unique in-stream decomposition patterns. Tallgrass prairie streams lack the abundant woody-debris dams found in forested streams. As a result, the frequent and prolonged dry periods, coupled with the prevalence of scouring floods, allow for very little in-stream decomposition of leaf packs (Matthrew 1988; Gray and Dodds 1998). As a result, entire groups of stream detritivores (shredders) are missing from the aquatic fauna of tallgrass prairie streams.

The extreme variability in prairie stream discharge and environment selects for organisms that have stress-resistant life stages, short generation times, rapid growth, rapid colonization potential, or combinations of these traits (Matthews 1988; Gray and Dodds 1998). These organisms are often able to re-colonize streams within weeks after drying or flooding.

Prairie Vegetation and Soils: Streamflow of prairie streams is affected by high water demands of native terrestrial vegetation, particularly in late summer and early fall when evapotranspiration rates are high and rainfall is scarce (Gray et al. 1998). Soil losses due to sheet or rill erosion are typically low in tallgrass prairie – even in burned prairies, surface roughness is adequate to maintain low overland flow velocities. Surface litter, soil porosity, and high soil organic matter content result in low surface runoff (Seastedt 1995).

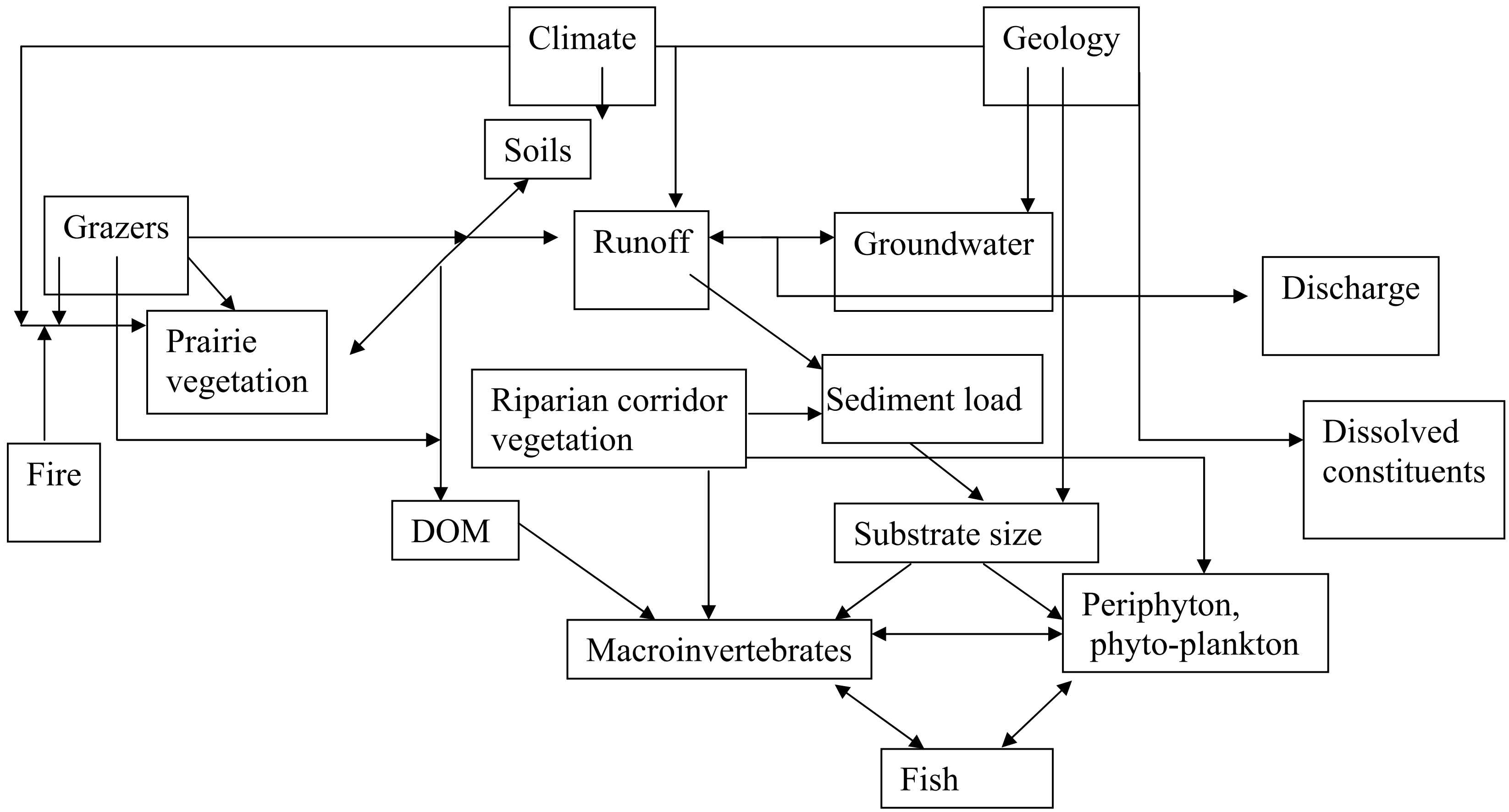
First- and second-order prairie streams typically flow through treeless vegetation. High light conditions result in within-stream primary production as the main organic matter input (Gray and Dodds 1998). In contrast, forested reaches of prairie streams respond similarly to other forest streams during periods of stable flow, in that allochthonous inputs, especially leaf litter, predominate. In-stream primary production is low due to low nutrient levels and shading by riparian trees.

The transfer of limiting resources from terrestrial to aquatic systems of tallgrass prairie is limited by relatively tight nutrient cycling within the terrestrial system (Gray et al. 1998). While exceptionally large C and N pools exist in prairie soils, "leakage" of these nutrients into prairie streams is highly restricted (Blair et al. 1998). Limited nutrient flow into prairie streams has significant consequences for aquatic food webs. Given that prairie streams have little organic C input from terrestrial vegetation, and that light levels are typically high in grassland streams, nutrient availability probably constrains primary production (Dodds et al. 1996; Gray et al. 1998). When more nutrient-rich groundwater enters streams, it is stripped of nutrients as it flows downstream (Tate 1990).

Table 7. Primary natural drivers and their effects on aquatic prairie ecosystems.

AQUATIC PRAIRIE ECOSYSTEM -- NATURAL DRIVERS		
Driver	***Resource***	***Effect***
CLIMATE (drought, floods)	Prairie streams	Highly variable streamflow with stable flows during spring/early summer, and intermittent to dry conditions during late summer & winter
	Macroinvertebrate communities	Communities dominated by small, rapidly growing species that can colonize quickly following disturbance
	Fish communities	Plains species relatively tolerant of hypoxia and high temperature variability/maxima
	Fish communities	Headwater springs provide important refugia during intermittent or dry conditions
PRAIRIE SOILS		High infiltration and soil water storage capacity of prairie soils results in low surface runoff
PRAIRIE VEGETATION	Prairie streams	High water demand in late summer, early fall contributes to low flow conditions; "tight" nutrient cycling by prairie vegetation results in low within-stream N concentrations
RIPARIAN CORRIDOR VEGETATION	Periphyton, phytoplankton, Macrophytes	Organic matter inputs primarily from within-stream primary production due to high light availability

Figure 5. Relationships between core abiotic and biotic components of prairie streams
Sources include Gray and Dodds (1998), Gray et al. (1998), Fausch and Bestgen (1996).



Current Anthropogenic Stressors

Knopf and Samson's (1996) description of today's prairie landscape provides a short overview of the most significant ecological alterations following European settlement.

The Prairie Landscape in 1996

Condensed from Knopf and Samson (1996)

The arrival of European descendents on the North American grasslands drastically altered the face of the landscape as well as ecological relationships within the biota. The overwhelming influence has been to modulate the inherent range of natural variation in ecological drivers of the prairie. Water management in the shortgrass and mixed-grass regions has locally removed the threat of periodic drought, resulting in increased cultivation and a westward extension of cereal grain agriculture. Fire suppression in the tallgrass and mixed-grass prairie has led to loss of species richness.

Cultivation and residential and industrial development have obliterated potential habitats for many vertebrate species locally. Total losses of native prairie range from 20% of shortgrass prairie in Wyoming to greater than 99% of tallgrass prairie in Illinois and Iowa. Overall, estimates of conversion of native prairie to either cropland or pastureland in the United States range from 29% of shortgrass, 41% of mixed-grass, and more than 99% of tallgrass landscapes (U.S. Dept of Agriculture 1987). Pastureland provides surrogate prairie habitat for some vertebrate species of the eastern Plains (Herkert 1993; 1994).

The loss of native grasslands as potential vertebrate habitats is even more devastating as remnant grasslands become more and more fragmented and isolated. The effects of fragmentation are threefold. First, many species of vertebrates require large, intact parcels of grassland for survival and reproduction (Samson 1980; Herkert 1994). As remnants decrease in size, these area-sensitive species are progressively extirpated locally. Second, as remnants become more isolated, the probability of colonization/recolonization of a patch decreases with distance from another patch (Kaufman and Kaufman 1996). Third, populations in isolated patches suffer from genetic inbreeding and accelerated rates of genetic drift (Benedict et al. 1996)…..

The estimated tens of millions of bison on the western Plains were replaced by an estimated 45 million cows and an equal number of domestic sheep by 1890 (Fedkiw 1989)… Management of cattle with fences has created endless homogeneous landscapes by removing the differential intensities of grazing among sites that historically created the mosaic of habitats necessary to support many species (Knopf 1996)… The uniformity of grazing management on the Great Plains probably has a more negative effect on endemic avian assemblages than the actual presence of livestock or the consequences of grazing (Knopf 1996).

Prairie streams had a strong riffle/pool structure that resembled more a series of seasonally connected small ponds or lakes during periods of low flow (Brown and Matthews 1996). Size of pools increased and length of riffles generally decreased moving down the drainage; all except the Missouri River periodically may have become intermittent in periods of drought. Today, water diversion and ground-water pumping have accentuated the intermittency of these streams on most of the Great Plains.

A less noticeable, but equally pervasive, threat to native fishes has been the rampant accidental and deliberate introduction of alien (North American species native to biogeographic provinces other than the Great Plains) and exotic (species from other continents) fishes into native streams. Ross (1991) reported that more than three of every four introductions of exotic fishes resulted in declines in populations of indigenous species.

Across the northern Great Plains, historic natural wetlands have been destroyed at an alarming rate. Estimates of wetland loss range from 86% in tallgrass prairie states (Illinois and Iowa) to 40% in Montana (Dahl 1990)….Drainage of wetlands and conversion of the landscape to row cropping continues to destroy these major breeding grounds for waterfowl populations (Betheke and Nudds 1995).

Fragmentation and isolation, fire suppression, loss of ungulate grazers, alteration of stream hydrology, and introduction of exotic species all act as stressors on prairie ecosystems today. Several Prairie Cluster parks are also facing growing developmental pressures on their boundaries. Cultural use, including trail-related impacts in sensitive areas and protected usage by Native American groups, may also be affecting park resources.

One could argue that ecosystem models are barely relevant to the management of small prairie remnants such as those that occur within Prairie Cluster parks. These modest patches of prairie seem insignificant in comparison to the vast landscape that spanned the Great Plains one hundred years ago. Cut off from the driving forces of fire and grazing that worked at grand scales to maintain them, often isolated from sources of gene flow and recolonization – do remnant prairies still function as ecosystems, or are we merely maintaining prairie gardens? Considering the long generation lengths of many prairie dominants (many exceeding 100 years) and the prevalence of vegetative reproduction, it is clearly too soon to tell.

In the meantime, particularly within the tallgrass prairie region where over 99% of the original habitat has been lost, many prairie associations preserved within NPS units represent some of the best regional examples of unique prairie types. Resource managers have little choice but to actively manage remnant prairies to preserve their ecological integrity and biodiversity. They employ prescribed fire to mimic natural disturbance regimes, attempt to control exotic species invasions, and restore native prairie and savanna vegetation to disturbed sites. These management actions may also be viewed as stressors, undertaken in the hope of mimicking natural processes and effecting positive change to prairie ecosystems. Their ultimate success will be judged on whether remnant and restored prairies can support a diverse array of grassland species, including conservative prairie insects and vertebrates.

Tables 8 and 9 summarize current and potential anthropogenic stressors to terrestrial and aquatic prairie ecosystems; Figures 6 and 7 describe the relationships between these anthropogenic stressors and core abiotic and biotic ecosystem components. More detailed, park-specific descriptions of resource threats are provided in Appendix A.

Table 8a. Current anthropogenic stressors of terrestrial prairie ecosystems -- development and use impacts.

Stressor	*Resource*	*Effect*	*Indicator*
Adjacent Habitat Loss & Fragmentation			Land use change maps
Isolation of native plant populations	Grassland plant communities	Loss of colonization and pollination sources, resulting in reduced abundance or loss of native species	Plant community composition; pollinator abundance
Fire suppression	Grassland plant communities	Woody invasion of prairie; conversion of savanna to woodland	Woody seedling/sapling density
Reduced wildlife habitat	Woodland plant communities	Deer over-abundance resulting in selective browsing pressure, loss of forb species	Plant community composition using exclosures
Reduced wildlife habitat	Grassland birds communities	Increase in edge and ruderal species resulting in displacement of grassland species	Bird community composition, relative abundance
Isolation of rare populations	Rare species populations	Loss of re-colonization sources following local extinction; reduced gene flow between populations	Decreased population persistence; reduced genetic diversity
Exotic Species Invasion			
	Grassland plant communities	Displacement of native species, alteration in community composition, structure and diversity	Plant community composition; distribution, abundance of exotics
Elevated CO_2 levels	Grassland plant communities	Shifts in species' range	Changes in persistence/abundance of edge-of-range populations
Cultural Use			
Trail Development/Use	Grassland plant communities, unique habitats	Further fragmentation of remnant communities, corridors for exotic invasion, soil compaction	Plant community composition
Fencing for cattle, watering points,		Disrupt spatial distribution of grazing, reducing landscape heterogeneity; high-impact zones adjacent to water, shade	Reduced Beta diversity, compositional changes in high-impact zones
Over-grazing	Grassland plant communities	Increased allocation to foliar production, resulting in reduced root mass; more rapid N-cycling results in increased soil N availability -- reduces dominance of prairie grasses. Reduced root mass & soil compaction reduce soil moisture retention.	Plant community composition, dominance; increased abundance of exotic species; soil nitrogen availability, soil compaction
Over-grazing	Grassland bird communities	Changes in vegetation structure result in poorer habitat quality for grassland birds	Bird community composition, abundance, diversity
Quarrying pipestone	Rare species habitat	Pumping water from quarries may result in altered ground-water hydrology, ultimately affecting mesic prairie and stream habitats of T&E species	Rare species abundance, plant community composition, stream, groundwater hydrology

Table 8b. Current anthropogenic stressors of terrestrial prairie ecosystems -- resource management actions.

Stressor	***Resource***	***Effect***	***Indicator***
Prescribed Fire		Increased habitat heterogeneity and structural diversity	Distribution of community types; beta diversity; grassland bird diversity and abundance
	Grassland plant communities, unique habitats	Maintain prairie communities; potential for species losses related to fire seasonality and frequency	Community composition, abundance, diversity; guild abundance; butterfly diversity
	Oak savanna plant communities	Conversion of woodland to savanna	Overstory composition, basal area; understory composition
	Grassland bird communities	Changes in vegetation structure, habitat quality; potential for fire-related mortality during breeding season	Community composition, diversity, abundance; nesting success
	Ground-nesting vertebrates	Fire-related mortality	Community composition, abundance and diversity
	T&E plants	Improve quality of T&E plant habitat; potential for fire-related mortality	T&E species persistence, abundance
Prairie / Savanna Restoration	Historic grassland landscapes	Recreation of historic landscapes	Distribution of community types, Beta diversity
	Grassland plant communities	Increase extent of prairie/savanna areas, buffer remnants from exotic invasion	Communitiy composition, abundance & diversity approaching that of model plant community
	Grassland birds/vertebrates	Increase in habitat size	Community composition, abundance and diversity
Exotic Species Control			Distribution/size of exotic patches; frequency, abundance of invasive exotic species
	Grassland plant communities	Improve native communities	Community composition, abundance & diversity
	T&E species habitat	Improve quality of T&E plant habitat	T&E species persistence, abundance
	Woodland/savanna communities	Reduce abundance of targeted species	Density of woody species
	T&E species	Improve quality of T&E habitat	T&E plant population size

Figure 6. Relationships between anthropogenic stressors, and core abiotic and biotic components affecting terrestrial prairie ecosystems. ***Modified from Hartnett and Fay (1998).***

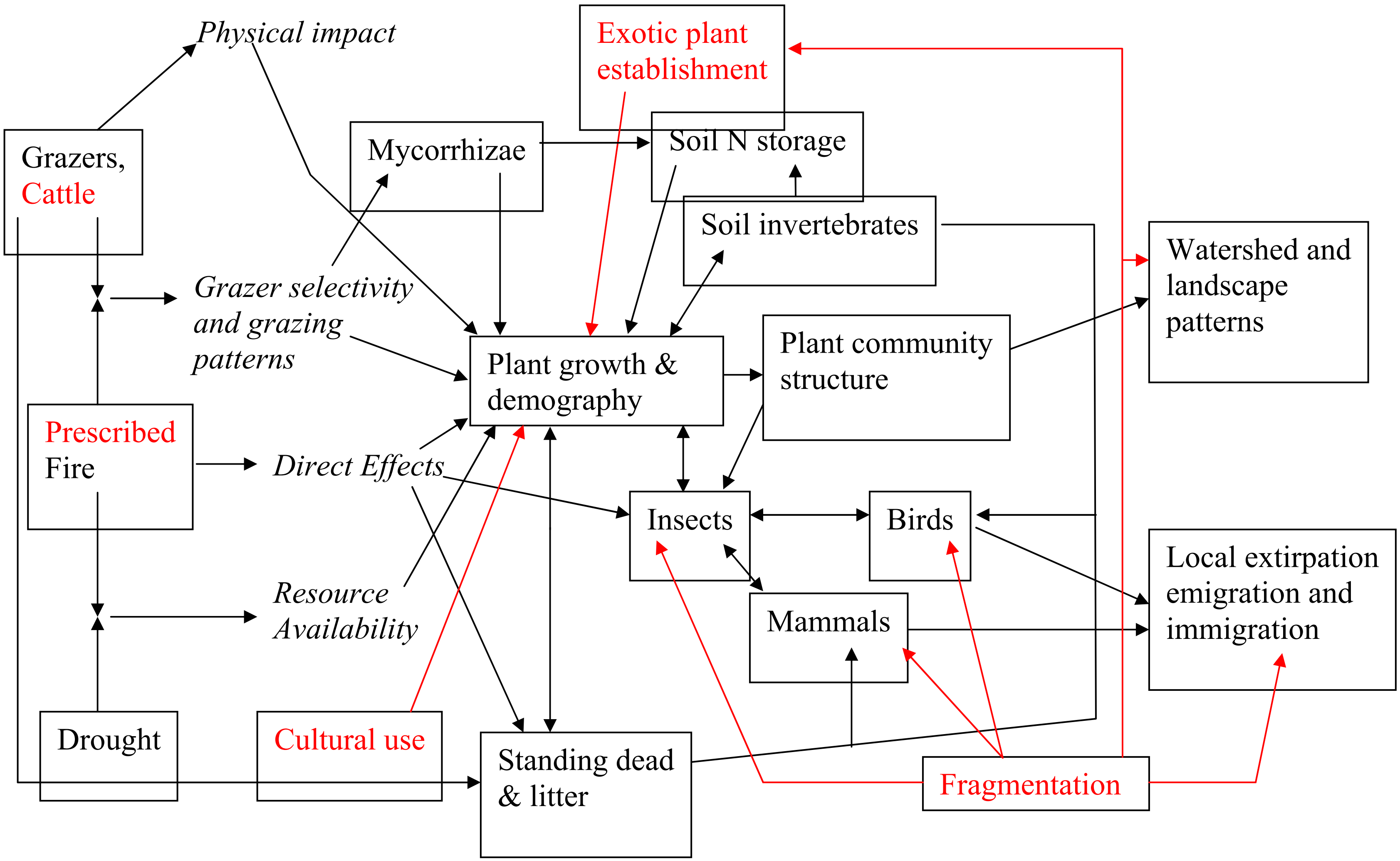
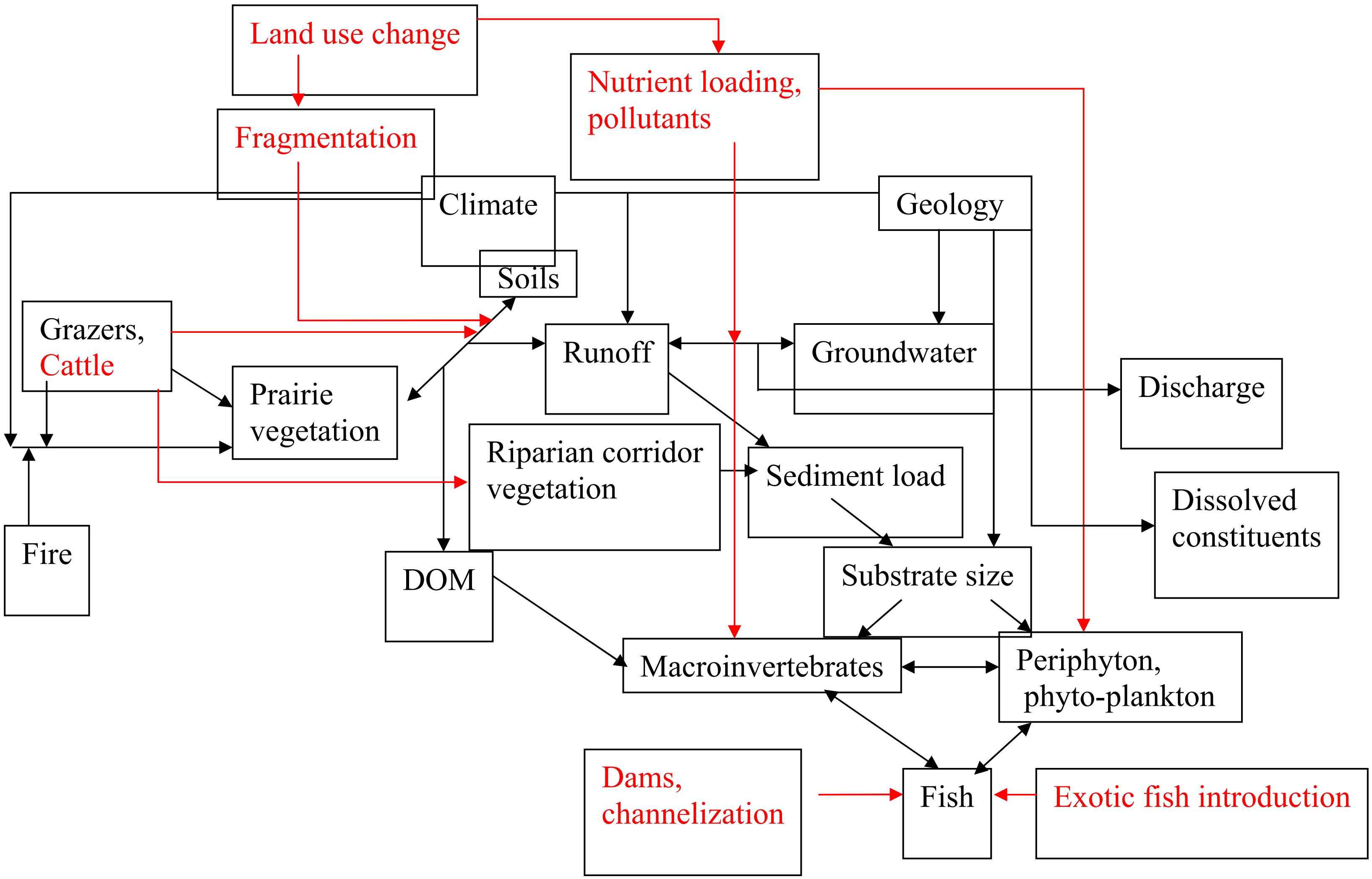


Table 9. Current anthropogenic stressors of aquatic prairie ecosystems -- development and use impacts.

Stressor	*Resource*	*Effect*	*Indicator*
Water pollution			Pollutant assays, water chemistry
	Streams	Nutrient enrichment resulting in loss of pollution intolerant species	Loss of fish species; decline in macroinvertebrate indices
	Groundwater		Pollutant assays, water chemistry
	Fish, amphibians	Accumulation of toxins	Declines in diversity, abundance; tissue or sediment assays
Unrestricted cattle access to springs	Spring water quality	Nutrient enrichment resulting in loss of pollution intolerant species; possible degradation/loss of refugia for unique prairie fishes & macroinvertebrates	Aquatic macroinvertebrate indices; rare fish population persisitence, abundance
Diversion dams, ponds, dewatered reaches	Fish communities, rare fish species	Impede upstream dispersal of adults & juveniles; interrupt downstream dispersal of eggs, larvae	Loss of fish species, declines in persistence, abundance of rare fish species
Stocking ponds for fishing, introduction of exotic bait fish	Fish communities, rare fish species	Predation, interspecific competition, hybridization with non-native congeners	Loss of fish species; declines in persistence, abundance of rare fish species
Stocking ponds for fishing	Amphibians	Predation of eggs and larvae	Declines in amphibian diversity, abundance
Water diversion, ground water pumping	Stream flow, ground water reserves	Eccentuate intermittency of prairie streams resulting in prolonged periods of anoxia & high water temperatures	Stream gauges; macroinvertebrate indices in mapped pools/riffles
Loss of riparian corridor vegetation	Stream water quality	Increased sedimentation rates	Measures of turbidity, embeddedness, stream bank erosion rates

Figure 7. Relationship between anthropogenic stressors, core abiotic, and core biotic components affecting biota of prairie streams. ***Sources include Gray and Dodds (1998), Gray et al. (1998), Fausch and Bestgen (1996).***



3. Review monitoring components within conceptual model context.

The exercise of first constructing simple models of the natural drivers of prairie ecosystems, and then incorporating current anthropogenic stressors has proven useful in reviewing our progress toward developing a monitoring program. In particular, it has underscored the defining, intrinsic climatic variability of prairie ecosytems and the resulting adaptive responses of prairie flora and fauna. It also reminds us of the complex interaction of climate, fire and grazing that historically regulated prairie ecosystems. The exercise has clarified the difficult task of detecting human-induced patterns of change from naturally high background variability.

One result of the exercise will be to strengthen efforts toward integrating climate data with our core datasets (Table 10). Weather stations were installed at PIPE and WICR by BRD/USGS to track microclimate related to population dynamics of the two federally listed rare plants. We will begin incorporating climate data from these stations or the nearest NOAA reporting stations into our interpretation of plant community and macroinvertebrate data.

Similarly, aquatic macroinvertebrate data should be more closely linked to a season-long record of streamflow. We will investigate using data from the nearest USGS gauging stations and explore the feasibility of park personnel taking regular staff gauge readings. The aquatic model also defined key physical and chemical attributes of prairie streams, highlighting the likely shift from N-limitation during normal flow conditions to temperature/oxygen limitation during low-flow conditions. We will also consider monitoring a few more in-stream physical/chemical parameters (i.e. to assess sediment loads, oxygen limitation during low-flow conditions, etc.).

In general, the conceptual models corroborate the original selection of plant communities, aquatic macroinvertebrates, and rare species populations as core indicators of ecosystem integrity. They also support the idea that monitoring grassland birds (in the larger parks) and butterfly assemblages will provide further evidence of structural diversity and habitat heterogeneity. The terrestrial model brought out the important roles of bison grazing and variable fire seasonality/frequency in maintaining landscape heterogeneity. This suggests the need to incorporate measures of patchiness, such as beta diversity, into the plant community monitoring protocol.

In terms of considering new monitoring directions, the conceptual models brought to the forefront the important role of prairie soils in maintaining both terrestrial and aquatic ecosystems. The high organic matter content resulting from below-ground prairie grass production, high moisture-holding capacity and low nitrogen availability are defining characteristics of prairie ecosystems. Particularly, in parks that include moderate to heavy grazing, incorporating a soil monitoring component (e.g. soil porosity & compaction, organic matter content, nitrogen availability) may prove interesting.

Table 10a. Monitoring implications derived from terrestrial prairie model.

KEY CHARACTERISTICS OF PRAIRIE ECOSYSTEMS	IMPLICATIONS FOR MONITORING
Interannual variability in ANPP (aboveground net primary production) in tallgrass prairie ecosystems is extreme.	High natural variability in ANPP may make it difficult to detect stressor-driven trends in foliar cover. Plant community monitoring should be accompanied by local climate data.
Prairie vegetation evolved in a nitrogen-limited environment.	Overgrazing of prairie vegetation may result in increased nitrogen availability, thus altering composition and increasing susceptibility to exotic species invasion.
Light to moderate grazing pressure may promote spatial heterogeneity within prairie ecosytems.	Plant community monitoring in grazed prairies should include a measure of beta (among-site) diversity.
Fire regimes that mimic natural fire frequency and seasonality may promote spatial heterogeneity within prairie ecosystems.	Plant community monitoring in prairies undergoing prescribed fire should include a measure of beta (among-site) diversity.
Heavy grazing pressure may result in soil compaction, resulting in reduced soil moisture infiltration.	Plant community monitoring in heavily grazed prairie should include measures of soil compaction/soil porosity.

Table 10b. Monitoring implications derived from aquatic prairie model.

KEY CHARACTERISTICS OF PRAIRIE ECOSYSTEMS	IMPLICATIONS FOR MONITORING
Prairie streams exhibit variable stream flow, periodic drought and unpredictable scouring floods.	Macroinvertebrate assemblages and Topeka shiner (*Notropis topeka*) populations should be monitored within the context of local precipitation and streamflow patterns.
Stream reaches flowing through treeless prairie are dominated by autochthonous production, while allochthonous inputs predominate in gallery forest reaches.	Macroinvertebrate monitoring within streams with prairie and gallery forest reaches should be stratified to track potentially different assemblages. Habitat data should be expanded to describe riparian corridor vegetation.
Prairie streams are nitrogen-limited.	Nutrient loading may shift resource limitation in prairie streams from nitrogen to other factors, such as oxygen.
High moisture infiltration rates of prairie soils and high surface roughness of prairie vegetation result in low surface erosion following heavy precipitation events.	Increasing sediment loads are indicative of changing land use within prairie watersheds.

C. Management Review of Monitoring Priorities

In FY 2000 the Servicewide I&M Program launched the Core Vital Signs Monitoring Program, organizing parks into 32 monitoring networks. Four parks of the PC-LTEM Program (EFMO, HOME, PIPE, and WICR) belong to the Heartland Network, while two parks (AGFO and SCBL) are part of the Northern Great Plains Network. The Heartland Network held two workshops in February and March of 2000 to focus on the initial steps of developing a monitoring program. PC-LTEM staff and resource managers from four of the six parks used the workshops as an opportunity to re-assess whether the PC-LTEM program was addressing each park's top resource issues. The workshop discussions also provided the catalyst for proposing the inclusion of Tallgrass Prairie National Preserve in the PC-LTEM Program (see Appendix B).

During the first workshop, outside scientists, MWR natural resource staff and park resource managers brainstormed to consider the most significant park resources, current and future stressors, and their likely effects. Once this step was completed, the participants developed long lists of potential monitoring projects or focus areas. *(Note -- we avoided using the term indicator in order to keep discussion focused on prioritization among broad resource areas. We felt that the comparison and ultimate selection among specific indicators was best accomplished by specialists within particular subject areas.)*

The network used the Analytic Hierarchy Process (Peterson et al. 1995) as a tool for I&M planning. We recognized that initial monitoring funds would only be adequate to implement the most important monitoring needs. However, we prioritized a broad range of potential projects in the hope that additional funding sources could be found. We used rating criteria defined by Peterson et al.(1995) because they provide a balanced consideration of whether monitoring data will contribute to management decision-making and/or ecological understanding (Table 11). Each resource manager was provided with a matrix of potential monitoring projects and the rating criteria to use in evaluating each project. They consulted with superintendents and park staff as they considered the importance of each potential project for their park. The second workshop provided an opportunity for frank discussion among resource managers and refinement of the scoring process. The final results for the four Prairie Cluster LTEM parks are presented in Table 12.

Table 11. Eight characteristics of good monitoring projects (Peterson et al. 1995) to rank potential projects.

Support management decision making
Influence external decisions relevant to park management
Satisfly legal mandates
Maintain familiarity with park resources
Understand ecosystem function
Provide background information for use by other projects and programs
Provide background information against which areas outside the park are compared
Provide an early warning of resource decline

Table 12. Park ratings of potential monitoring projects for EFMO, HOME, PIPE and WICR.

Potential Monitoring Projects	T&E species, species of special concern	Water quality	Plant communities (e.g. prairie, savanna, glades)	Habitats of concern, (flora & or faunal)	Birds (e.g. grassland, savanna, wetland)	Invasive exotics - early warning and control effectiveness	Butterflies as indicators of prairie health	Herps (fire effects)	Deer & deer effects	Human impacts to natural resources	Weather	Adjacent land use changes
Effigy Mounds	74	66	74	70	56	74	55	48	55	52	60	65
Homestead	68	65	72	66	48	66	62	61	67	57	61	49
Pipestone	75	66	66	68	58	64	59	65	20	57	55	67
Wilson's Creek	60	66	57	55	45	61	52	51	61	62	35	57
average	69.3	65.8	67.3	64.8	51.8	66.3	57.0	56.3	50.8	57.0	52.8	59.5

Overall, the monitoring priorities established by the park resource managers are well reflected in the current monitoring components of the Prairie Cluster LTEM Program. The resource managers rated T&E species and grassland plant communities as their highest monitoring priorities. These projects describe the major emphases of the Prairie Cluster LTEM Program. Similarly, monitoring is underway to assess water quality, habitats of concern, and adjacent land use change. The one issue that is not adequately represented by the program is providing early warning of exotic species invasion. Plant community monitoring will detect changes in the frequency and abundance of invasive exotic plants. However, the parks also need extensive monitoring to detect the initial stages of exotic invasion. This project was identified in the original program proposal, but was not developed by BRD/USGS during the design phase.

PART 2. SUMMARY OF MONITORING COMPONENTS

Terrestrial and Aquatic Ecosystems

Landscape Monitoring

1. Adjacent land use

Terrestrial Ecosystem

Community Monitoring

2. Grassland plant communities
3. Grassland birds
4. Grassland butterflies

Population Monitoring

5. State-listed T&E plants
6. Missouri bladderpod (*Lesquerella filiformis*)
7. Western prairie fringed orchid (*Platanthera praeclara*)
8. Black-tailed prairie dog (*Cynomis ludovicianus*)

Environmental Monitoring

9. Local climate

Aquatic Ecosystem

Community Monitoring

10. Macroinvertebrates as indicators of stream health

Population Monitoring

11. Topeka shiner (*Notropis topeka*)

1. Adjacent Land Use (in development)

Problem statement and justification

The underlying theme of the Prairie Cluster Prototype LTEM Program is the question of whether the species, communities and ecological processes of small remnant and restored prairies are sustainable in the face of adjacent habitat loss and fragmentation. The relatively small Prairie Cluster parks are bordered by adjacent land uses ranging from cattle grazing of native rangeland (AGFO), to cultivated agricultural fields (PIPE), to rapid urban development (WICR). A key aspect of measuring the effects of isolation and fragmentation is documenting past and current land uses and analyzing rates of land use change.

Monitoring questions and approach

How has land use adjacent to the parks changed in the last 50-60 years?

- Have there been direct losses of adjacent natural areas?
- Has adjacent land been converted from semi-natural land uses (e.g. native rangeland, prairie hay meadows, woodlots) to non-native vegetation types?
- How is human population pressure affecting adjacent land use (i.e. point-source pollution, road development, urbanization)?

Aerial photography from three time periods (1940s, 1960s, 1990s) has been acquired and ortho-photographs produced for the six Prairie Cluster parks. A project is underway in three parks (EFMO, PIPE, WICR) to classify and detect changes in land use/land cover over the time span of the acquired imagery. The current land use/land cover map will form a baseline for detecting future change. Imagery will be acquired at ten-year intervals to document future changes in land use adjacent to the parks.

2. Grassland Plant Communities

Protocol: Willson, G.D., L.P. Thomas, M.D. DeBacker, W.M. Rizzo and C. Buck. 2001. Plant community monitoring protocol for six prairie parks. Biological Resources Division, U.S. Geological Survey, prepared for Great Plains Prairie Cluster Long-Term Ecological Monitoring Program, Republic, MO.

Problem statement and justification

In all Prairie Cluster parks, grassland plant communities are important natural resources and the focus of much management attention. Although small in size, Prairie Cluster parks represent the few remaining refuges where the once widespread prairie grasslands persist. Furthermore, intact prairie represents the historical landscape context for the cultural resources the parks are intended to interpret. Profound alteration of lands in the mid-continent to agricultural use has permanently disrupted the natural forces of wildfire and grazing. Consequently, managers employ prescribed fire, manual removal of woody species, exotic control and restoration to maintain the prairie. To date, the effectiveness of management actions in sustaining prairie in the face of fragmentation, disruption of natural disturbance regimes, and exotic species encroachment is uncertain.

Model of key drivers

The natural drivers and anthropogenic stressors effecting prairie plant communities are described in Part 1, Section B.2. (Table 6 and Figure 4 for natural drivers; Table 8 and Figure 6 for anthropogenic influences).

Monitoring questions and approach

1. What is the current species composition, structure, and diversity of remnant and restored prairies?
    - Measure vascular plant species composition and foliar cover in permanent plots.
2. Is the structure, composition, and diversity of remnant and restored prairies changing? If so, is this change directional, cyclic, or random?
    - Monitor vascular plant species composition and foliar cover at regular intervals.
    - Initially, monitor for several consecutive years to assess inter-annual variability and obtain a multi-year baseline.
3. Are trends in species composition, structure, and diversity correlated with climatic variables or management activities, such as prescribed fire?
    - Record management actions and acquire climatic data for correlation with monitoring results.

Management implications

- Monitoring results will measure the success of management in sustaining prairie in a fragmented landscape.
- Monitoring results help determine if prescribed fire and exotic control objectives are being met.
- Integrating climate data with monitoring results helps managers distinguish natural variability from directional change that results from and/or requires management intervention.
- Monitoring results inform managers about their success in maintaining rare species habitat, and when integrated with rare plant monitoring data, indicate whether habitat preservation efforts are translated into stable rare plant populations.

3. Grassland Birds (in development)

Protocol: Peitz, D.G. In preparation. Bird community monitoring protocol for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas. Prairie Cluster Prototype LTEM Program, National Park Service, Republic, MO.

Problem statement and justification

North American grasslands once covered vast areas of the continent. However, at present most have been altered or have ceased to exist as functioning prairie ecosystems with their full compliment of plant and animal species. Of all the North American grasslands, tall- and mid-grass prairies are among the most severely altered (Joern and Keeler 1995). Over the past 25 years, data from the U.S. Geological Survey's North American Breeding Bird Survey indicate that almost 70% of the 29 grassland bird species adequately surveyed showed evidence of declining populations (Knopf 1994; U.S. Department of Interior 1996; Sauer et al. 2000).

Grassland birds were initially selected for monitoring as indicators of overall prairie ecosystem health. Grassland bird inventories were conducted in the Prairie Cluster Prototype parks in 1998 and 1999 (Powell 2000) as a preliminary step toward developing long-term monitoring. Dr. Powell concluded that grassland habitat within most of the Prairie Cluster Prototype parks was insufficient to support large numbers of grassland birds. She recommended implementing bird community monitoring at Agate Fossil Beds NM, the only Prairie Cluster prototype park where grassland bird species represented a relatively high proportion (60%) of bird species present.

Model of key drivers

A conceptual model is presented in Figure 8. Key natural components of the model are as follows:

- Drought or severe weather events, especially during nesting and brood rearing, and predation limit reproductive success and survival of individuals.
- Vegetative structure and composition determine food availability, thus influencing growth and survival of individuals.
- Vegetative structure determines the quality and availability of nesting sites.

Model components of human origin or under direct human influence are as follows:

- Habitat fragmentation resulting from urbanization and agriculture negatively influences prairie birds by isolating populations and exposing them to greater threats from predation, nest parasitism, disease, and genetic depression.
- Moderate grazing, prescribed fire, and chaining are agricultural practices that have helped to maintain the integrity of some native prairies. However, any one of these activities implemented during the breeding or brood rearing season may result in a complete reproductive failure for the affected area.
- Agricultural pesticides and herbicides can cause direct mortality to affected individuals, or they may indirectly influence populations through reduced reproductive success.

Pesticides and herbicides have a greater influence on bird species at the top of the food chain as they concentrate toxins ingested by their prey base.

- Suppression of wildfires and the introduction of invasive exotics alter the structural composition and suitability of vegetation for prairie birds.

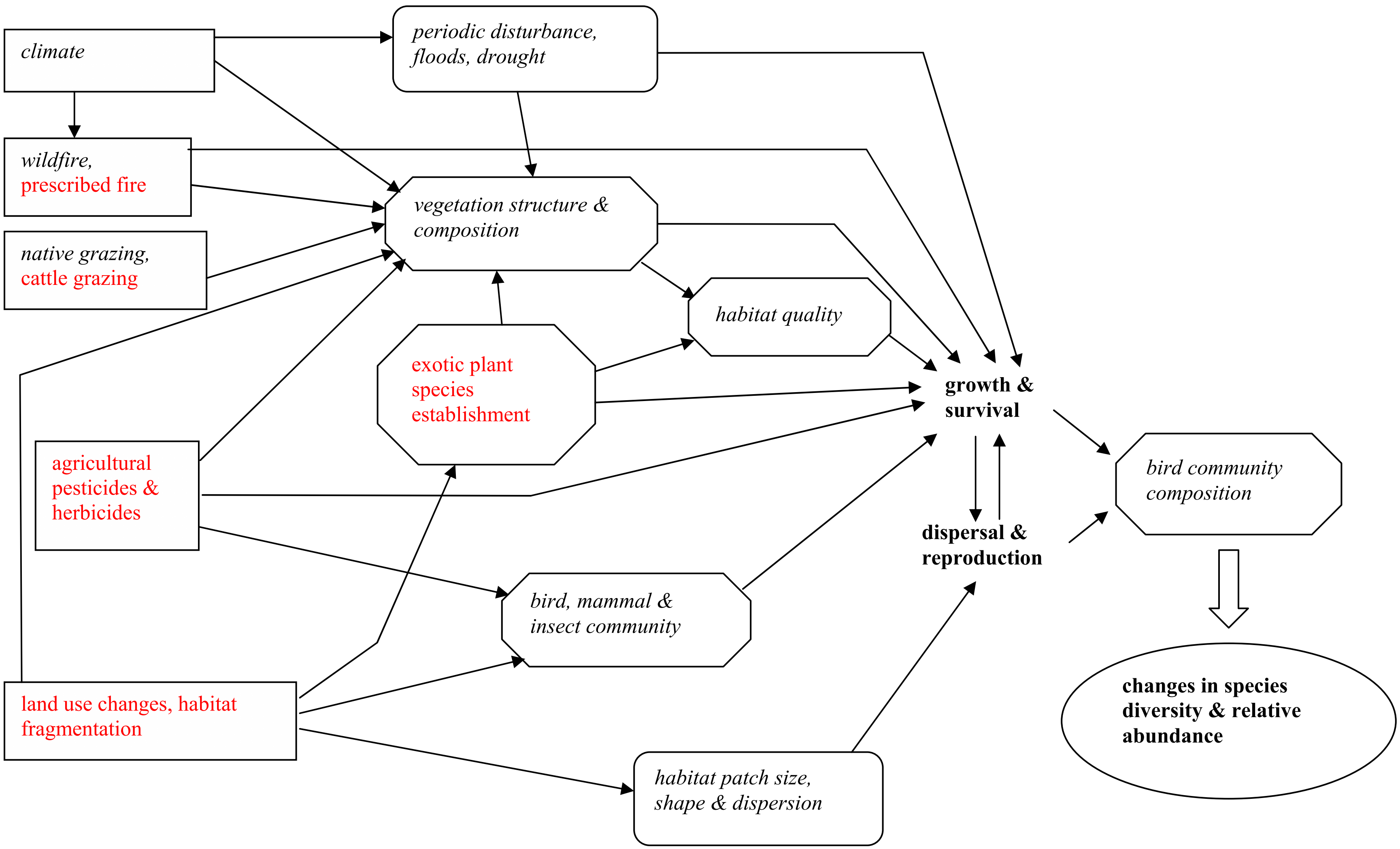
Monitoring questions and approach

1. What is the current status in grassland bird populations? What are the long-term abundance trends?
    - Annual censuses conducted during the breeding season using variable circular plot counts to track the location, abundance, and trends of bird species through time.
2. What is the current condition of prairie habitat, and how is it changing through time?
    - Plant community composition and structure data are collected in conjunction with annual breeding bird surveys so that monitoring results can be tracked over time and correlated with habitat characteristics.
3. Are changes in population status or habitat quality correlated with management regimes?
    - Record management actions for correlation with monitoring results.

Management implications

- Monitoring data from bird communities can be used as an indicator of overall prairie health within park boundaries.
- Correlating annual bird survey data with habitat data helps to clarify the relationship between prairie management, habitat quality and grassland bird communities.
- Correlation of bird data with land use practices will help assess the effects of these practices on prairie health within a park.

Figure 8. Conceptual model of prairie bird community dynamics.



4. **Grassland Butterflies** (developed but not implemented; recommended within-year monitoring frequency exceeds staff capabilities)

Protocol: Debinski, D., S. Mahady, W.M. Rizzo, and G.D. Willson. 2000. Butterfly monitoring protocol for four prairie parks. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 25 p.

Problem statement and justification

Only a very small fraction of native tallgrass prairie and oak savanna vegetation remains intact. Destruction and fragmentation of these habitats has untold consequences on their biodiversity. The butterfly community can be used as an indicator of the overall health of these ecosystems, in the same way that aquatic macroinvertebrates have been used as indicators of water quality (Debinski et al. 2000). Butterflies are relatively easy to identify, and their habitat preferences and movements in response to habitat are relatively well understood (Debinski et al. 2000).

Model of key drivers

A conceptual model is presented in Figure 9. Key natural components of the model are as follows:
- Weather patterns, periodic disturbance, and natural predation by birds, mammals, insects, and parasitoids all limit the survival of individuals. Forage quality and plant community composition and structure also determine the growth and survival of individuals.
- The structure of the vegetation also will influence the dispersal and reproduction of butterflies. Nectar availability is an important component of habitat choice and movement patterns of adult butterflies, and is determined by the composition of the plant community. Dispersal patterns are also influenced by weather events.

Model components of human origin or under direct human influence are as follows:
- Wildfire supression and exotic species encroachment change the character of prairie and savanna vegetation, altering its suitability for butterfly populations (Mahady 1999).
- Grazing and prescribed fire are two management methods available and in use to maintain the native character of prairie and savanna vegetation. Prescribed fire has both direct and indirect effects on the survival and growth of butterflies.
- Urban development, habitat destruction, and fragmentation influence dispersal patterns of butterflies (Schultz and Crone 2001). Fragmentation alters the composition of native plant communities by isolating them from recolonization from neighboring sites, and by increasing the exposure to colonization events by exotic species. Fragmentation also has direct and indirect influences on bird, mammal and insect predator populations.
- Agricultural pesticides and herbicides can have direct influences on exposed butterflies. In addition, the use of introduced insects for biological control of agricultural pests can have ancillary repercussions on butterfly populations.
- Global climate change is likely to influence climate and weather patterns in an unpredictable manner. Such changes will probably affect the nature of the plant community and on dispersal and migration patterns of butterflies.

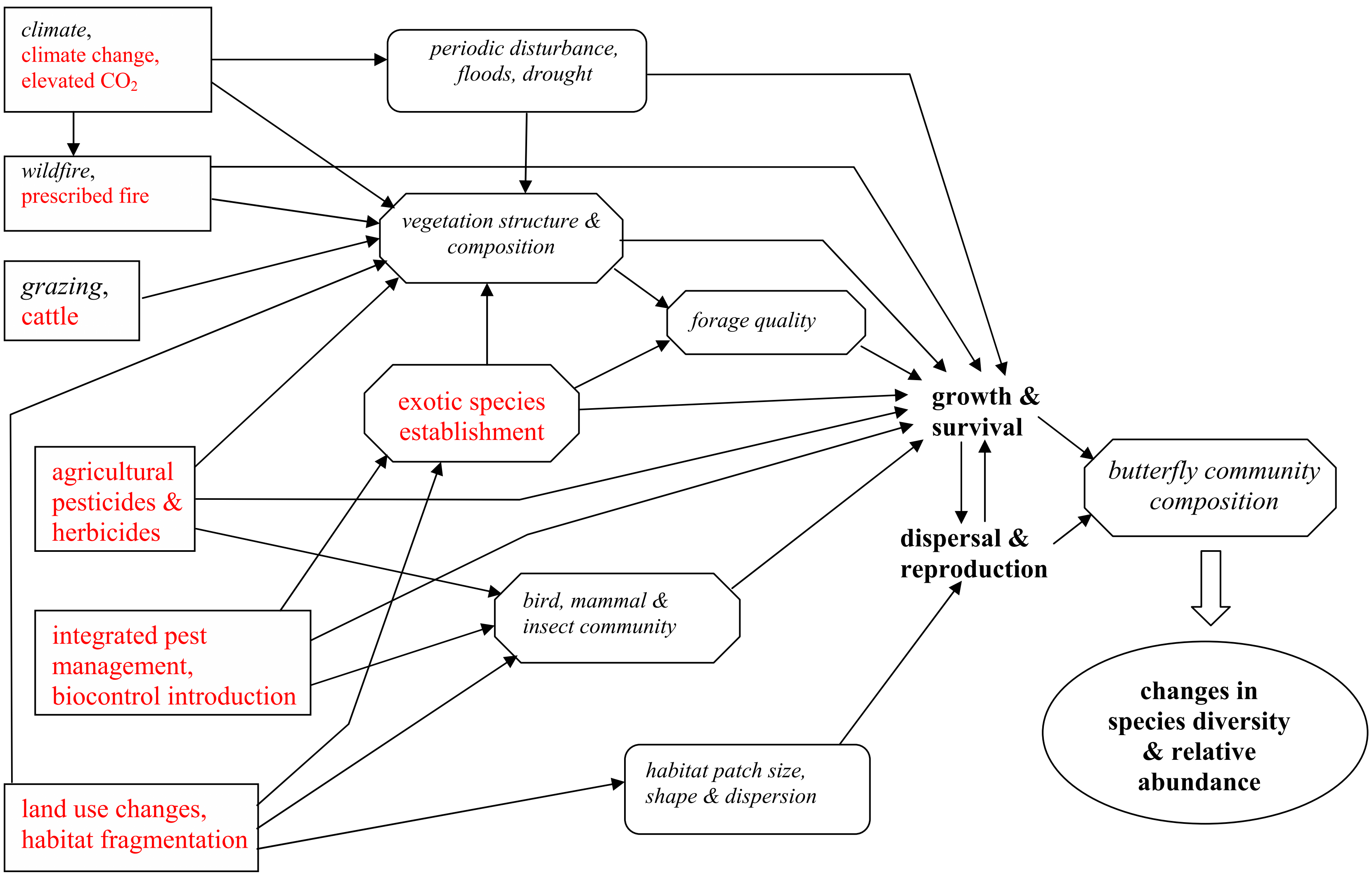
Monitoring questions and approach

1. How does the composition, abundance, and richness of the butterfly community fluctuate over time?
   - Census data are to be collected from 50-m transects (n = 6 per habitat type), four times per year.
2. How do changes in community composition and abundance relate to changes in the plant community?
   - Permanent butterfly transects are located adjacent to vegetation transects so that the two data sets can be linked. Changes in butterfly communities can be correlated with changes in the diversity, richness, and dominance patterns of the plant community.

Management implications

- Monitoring data from butterfly populations can be used as an indicator of how specific land management activities (e.g., grazing, prescribed fire, herbicide application) affect the terrestrial invertebrate community as a whole.
- Trend data for butterfly guilds can be used to evaluate the effects of large scale processes (e.g., adjacent land use) on the dispersal and richness of the invertebrate community.
- Correlations between butterfly community changes and vegetation changes can be used by resource managers to assess the effectiveness of habitat restoration practices.

Figure 9. Conceptual model of butterfly community dynamics.



5. State-listed Threatened and Endangered Plants (in development)

DeBacker, M.D., L.P. Thomas and J.R. Boetsch. In preparation. A practical guide to monitoring rare plant species occurring in five prairie parks. Prairie Cluster Prototype LTEM Program, National Park Service, Republic, MO.

Problem statement and justification

The federal Endangered Species Act mandates conservation of nationally rare species; similarly, many states have endangered species legislation to protect species that are regionally rare. While not legally under the jurisdiction of state regulations, National Park Service policy obligates managers to protect these species. Furthermore, regional endemics and edge-of-range species are often indicative of unique habitats characterized by extreme edaphic conditions (e.g. rock outcrops) (Stebbins 1980; Kruckeberg & Rabinowitz 1985; Lesica & Allendorf 1995; Crins 1997; Locklear 1997). These habitats often represent rare natural features and support unusual species assemblages. Identifying and monitoring these unique habitats and their associated flora is an important step toward conserving regional diversity at both the species and community levels.

Model of key drivers

A conceptual model is presented in Figure 10. Key natural components of the model are as follows:

- Typically, rare plants occur in small populations often disjunct or peripheral to a broader distribution. Small populations have a greater probability of extinction due to random stochastic events (e.g. rockslide) or catastrophic demographic events (e.g. failure to set seed) (Brussard 1986).
- An equilibrium between local extinction and re-colonization sustains species that occur principally in small populations.
- In general, natural selection and genetic drift in small populations lead to reduced genetic variability within populations but greater genetic variability among populations. Consequently, populations of locally rare species frequently possess a disproportionate share of the genetic diversity of a species (Lessica & Allendorf 1995).

Key anthropogenic components of the model are as follows:

- Fragmentation of natural landscapes isolates small, rare plant populations and degrades the inter-population matrix for dispersal. Isolation reduces the probability of colonization and upsets the balance between local extinction and re-colonization.
- Many rare plant species have commercial value as ornamental or medicinal plants. Poaching threatens the persistence of rare plant populations.
- Many rare plant populations are disjunct or peripheral to larger populations and grow in conditions nearing their ecological limits. The persistence of these populations may be especially susceptible to global climate change.

Monitoring questions and approach

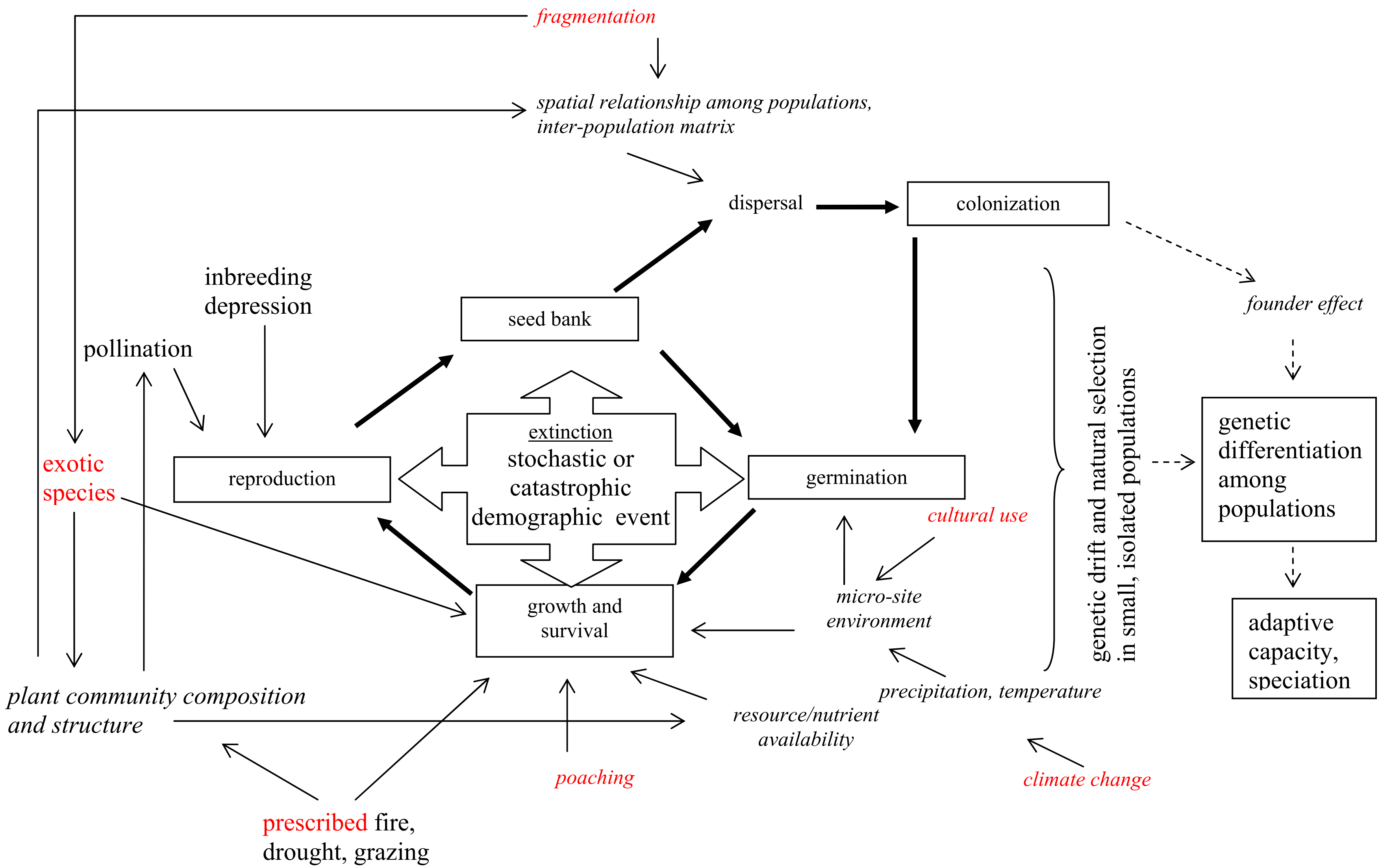
The rare plant monitoring protocol provides a framework for resource managers to select rare species for monitoring and identify an appropriate monitoring strategy. The protocol incorporates degree of rarity, potential threats and management issues to prioritize rare species for monitoring. Further, the protocol considers temporal and spatial distribution of the species and the availability of habitat in the park to suggest an appropriate monitoring strategy. Within each strategy, monitoring methods are described for three levels of monitoring intensity (distribution, persistence, and abundance).

1. Which rare species occur in the park and where are they located?
    - Research herbarium collections and state natural heritage records. Identify and map rare plant populations with GPS.
2. Are populations of rare plants persisting over time?
    - Periodically revisit known populations and search for new populations.
3. Is the size of rare plant populations changing over time?
    - For high priority species, measure abundance through complete census or sample.

Management implications

- Monitoring data allow managers to determine compliance with state conservation requirements.
- In the Prairie Cluster, managers frequently use prescribed fire to manage the habitat of rare species. Results allow managers to assess the effectiveness of prescribed fire in maintaining habitat quality and constituent species. Monitoring also serves as an early warning of any unanticipated deleterious effects.
- Knowing the distribution of rare plant populations helps managers when considering park land use issues and development.

Figure 10. Conceptual model of factors affecting rare plant population dynamics.



6. Missouri Bladderpod (*Lesquerella filiformis)*

Protocol: Kelrick, M.I. 2001. Missouri bladder-pod monitoring protocol for Wilson's Creek National Battlefield. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 28p.

Problem statement and justification

Missouri bladderpod (*Lesquerella filiformis* Rollins) was listed as Federally Endangered in 1987. Five populations are found at Wilson's Creek National Battlefield. This diminutive winter annual is restricted to limestone glades and rock outcrops in southwestern Missouri and northwestern Arkansas. Habitat conversion for urban development or agriculture threatens this species range-wide. The habitat structure of the limestone glades has been altered by woody species encroachment, a result of suppression of periodic wildfires that maintained an open character to glade vegetation. Glade habitat has also been altered and threatened by exotic species establishment; of particular concern are annual exotics such brome grass (*Bromus* species), which compete directly with Missouri bladderpod and can crowd it out (Thomas and Jackson 1990).

Model of key drivers

A conceptual model is presented in Figure 11. Key natural components of the model are:
- Missouri bladderpod plants germinate in fall with the onset of cool temperatures and autumn rainfall. Not all of the seed bank germinates in a given year, which is possibly an adaptive means of avoiding a population crash following a season of complete reproductive failure.
- The survival of germinated seedlings to maturity depends primarily on winter and springtime weather events (e.g. drought, freeze-thaw cycles and severe storm events), which cause frost heave and erosion of the shallow glade soils. Vegetation structure and composition mitigate these effects to a variable degree (Thomas 1996).
- Reproductive success of mature plants is influenced primarily by springtime weather patterns, and by the activity of insect pollinators. The length of the flowering period depends on the persistence of cool, wet springtime weather (Morgan 1986; USFWS 1988). During the flowering period, pollinator activity plays an important role in the cross-pollination of this species. Seed bank replenishment is reduced by fungal predation of seeds and fruits.

Model components of human origin or under direct human influence are as follows:
- Prescribed fire and mechanical removal of woody species have been employed by park managers in an attempt to maintain the open character of the glade habitat.
- Urbanization and concomitant landscape fragmentation influence the composition of native plant communities by isolating them from recolonization from neighboring sites, and by increasing the exposure to colonization events by exotic species. Fragmentation also has direct and indirect influences on wildlife and insect pollinators, which could have serious repercussions on Missouri bladderpod survival and reproduction.
- Human use of historically significant sites that coincide with Missouri bladderpod populations may result in trampling and soil compaction (Thomas and Willson 1992).
- Global climate change and elevated atmospheric CO_2 levels are likely to influence climate and weather patterns in an unpredictable manner. Such changes will probably affect the nature of the plant community, which will have direct and indirect effects on Missouri bladderpod.

Monitoring questions and approach

There are three main components to the monitoring for this species:
1. How does abundance fluctuate over time?
    - Annual censuses to track the abundance of the species through time. Population size has been observed to fluctuate widely from year to year, with the number of plants surviving to maturity ranging over several orders of magnitude – in some years none may survive to reproduce, so that local

population persistence depends on the resilience of the seed bank. Various sampling methods are being tested to improve the precision of abundance estimates so that long-term abundance trends can be detected reliably.

2. How does plant occurrence, survivorship and reproduction vary with habitat characteristics? Which factors determine the population size for this species?
    - Habitat data are collected simultaneously with annual abundance data so that local abundance patterns can be correlated with habitat characteristics.
    - Demographic sampling is undertaken periodically to determine which factors limit population size of Missouri bladderpod, and how survivorship and reproduction vary across glade microhabitats. Microsite conditions vary tremendously so that plants growing within a few meters of one another display drastically different survival and reproductive rates (Thomas 1996; Kelrick 2000).
3. How is the limestone glade habitat changing over time?
    - Glade vegetation is being monitored in two ways: 1) three vegetation transects placed at the largest population and sampled periodically; and 2) glade-wide habitat data collected systematically for two populations so that multi-year comparisons can be made.

Management implications

- Annual census data is crucial for monitoring long-term abundance trends, and for ensuring population persistence.
- Current management practices have been centered upon exotic species control and the reduction of woody vegetation by the combination of manual removal and small-scale prescribed fire. Vegetation monitoring data are essential for evaluating the success of habitat manipulation and restoration efforts.
- Information on how survivorship and reproduction vary with habitat characteristics over time can be used to develop a more informed and effective habitat management plan for Missouri bladderpod.

Figure 11a. Conceptual model of influences on habitat quality for Missouri bladderpod (*Lesquerella filiformis*).

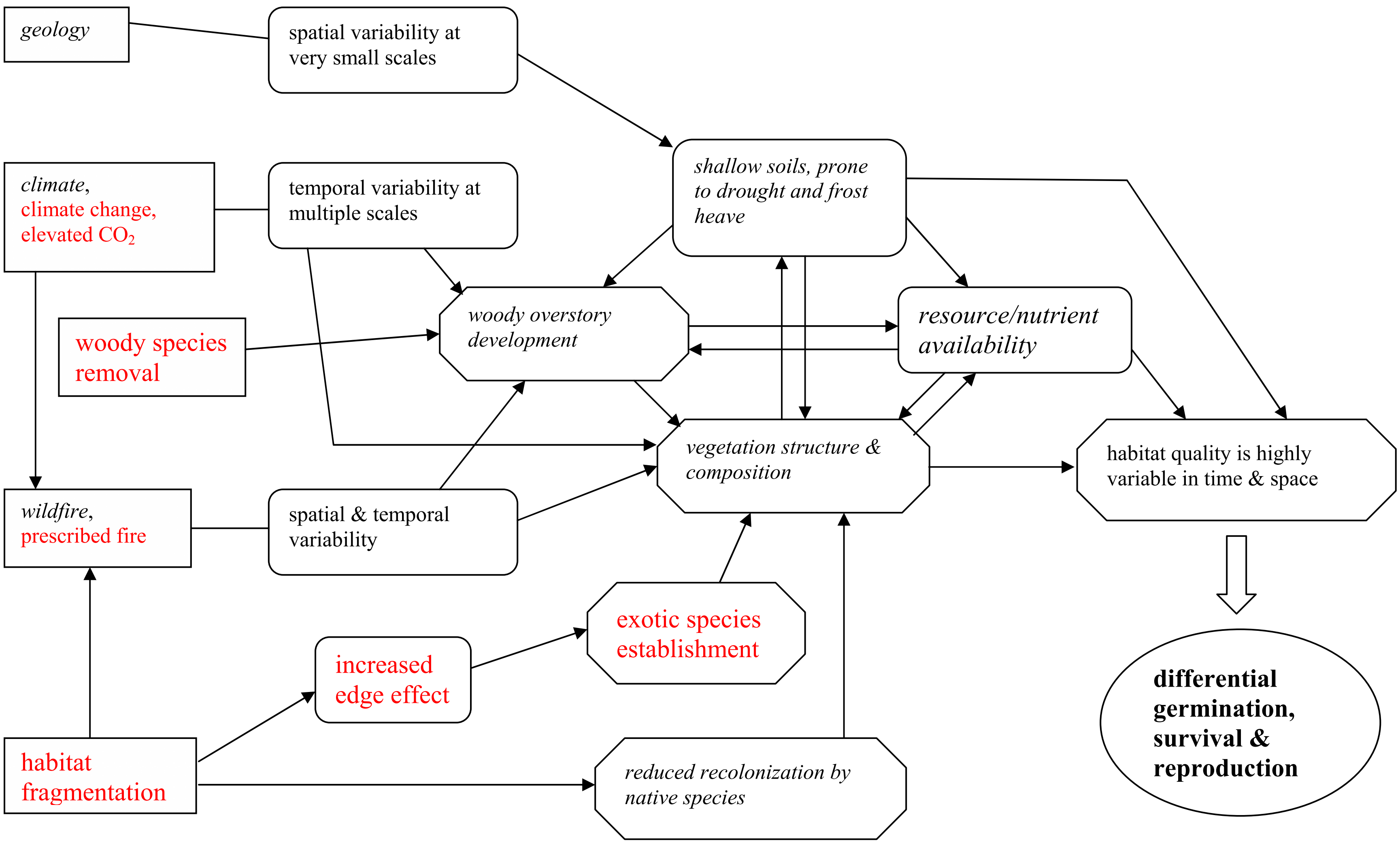
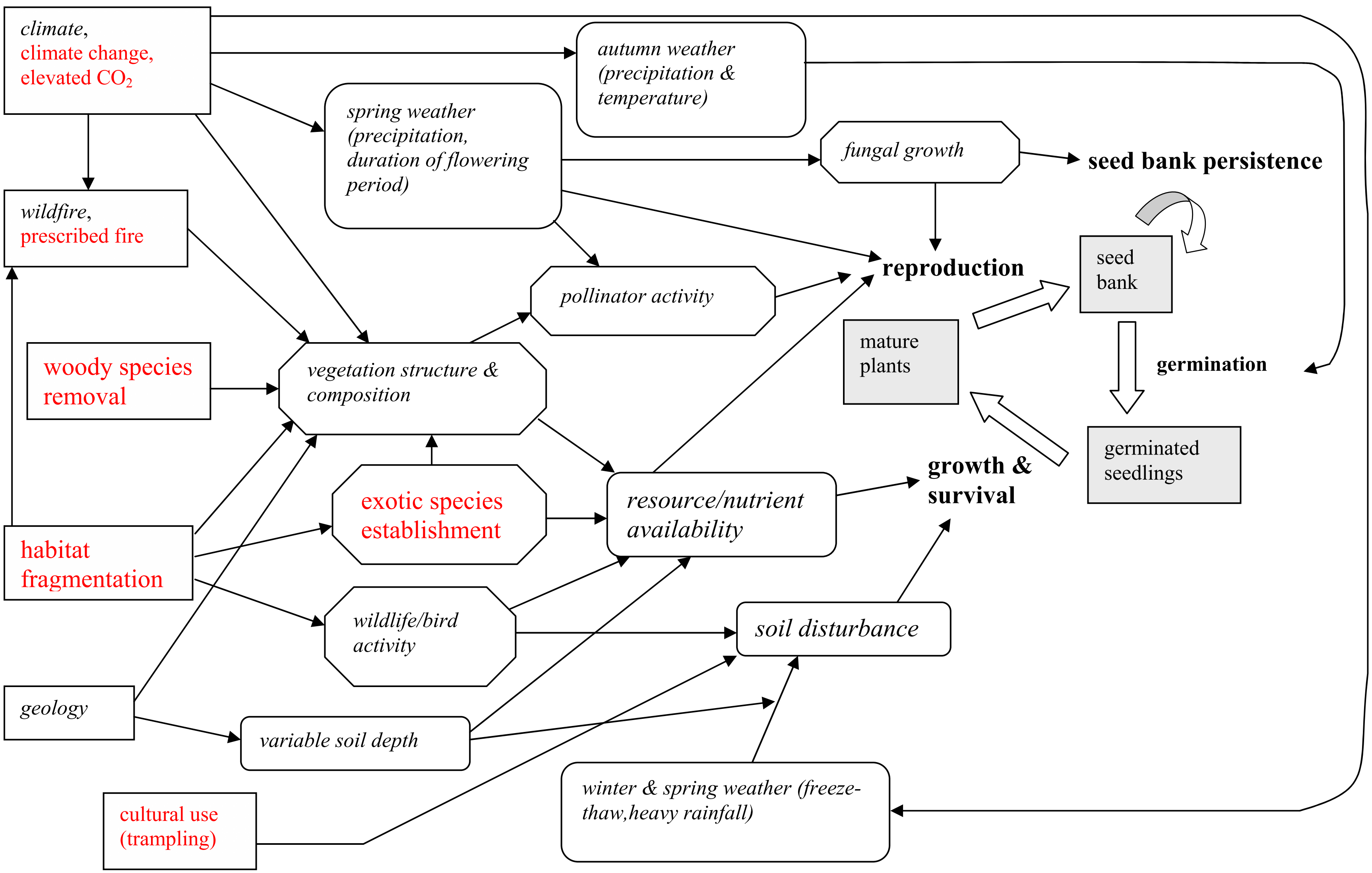


Figure 11b. Conceptual model of influences on the demographics cycle of Missouri bladderpod (*Lesquerella filiformis*).



7. Western Prairie Fringed Orchid (*Platanthera praeclara)*

Protocol: Willson, G.D. 2001. Western prairie fringed orchid monitoring protocol for Pipestone National Monument. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 18 p.

Problem statement and justification

The western prairie fringed orchid (*Platanthera praeclara*) was listed as threatened in 1989 by the U.S. Fish and Wildlife Service under the Endangered Species Act. Once widespread and locally common in the tallgrass prairie region, today the species persists only in a few, isolated populations in 38 counties across 7 states (USFWS 1994). Profound habitat loss is the principal cause of rarity with less than 4% of the original tallgrass prairie remaining.

Model of key drivers

A conceptual model is presented in Figure 12. Key natural components of the model are as follows:

- Reproductive individuals reach 12 dm in height and produce a determinate inflorescence consisting of up to 40 flowers that are dependent upon nocturnal moths for pollination. Fertile capsules produce thousands of microscopic seeds that are wind dispersed; however, germination requires inoculation by appropriate mycorrhizal fungus. Seedlings persist as underground saprophytes for several years before producing photosynthetic, above ground growth (Bowles 1983; Sheviak & Bowles 1986).
- The orchid grows principally on mesic to wet-mesic upland prairies (USFWS 1994). Annual growth and flowering are dependent upon adequate precipitation resulting in high soil moisture. Soil moisture determines whether a floral primordium develops in the tuber, and the subsequent growth of the tuber during the following growing season. Below average soil moisture may cause an absence of flowering or the onset of dormancy (Bowles 1983; Sheviak & Bowles 1986).
- Fire is an important force influencing the orchid's growth and persistence and is critical to the maintanence of tallgrass prairie. Mass flowering has been observed following fire (Currier 1982; Bowles 1983); however, other studies have failed to detect an effect (Sieg & Bjugstad 1993). Several ideas help explain the relationship. Fire increases nutrient and light availability promoting vigorous growth; however, fire also reduces the ability of soil to retain moisture. Fire, coupled with below average precipitation, may result in stunted growth and aborted flowers (Pleasants 1994). Finally, fire may promote mycorrhizal fungus effecting germination and vegetative growth (Bowles 1983).

Key anthropogenic components of the model are as follows:

- The remaining tallgrass prairie occurs primarily in small isolated patches (e.g. 112 acres of native tallgrass prairie at Pipestone National Monument). Fragmentation of the once continuous landscape results in the disruption of fire and grazing regimes, and encourages the encroachment of woody vegetation and establishment of exotic species. Further, fragmentation decreases the probability of successful dispersal and may limit pollinator visitation.
- In the absence of wildfire, mangers use prescribed fire to maintain the tallgrass prairie plant community and the orchid population.
- At Pipestone National Monument, significant hydrologic changes have taken place including the channeling of Pipestone Creek to drain wetlands upstream. Today, quarries adjacent to the orchid population are used by Native Americans to harvest pipestone and are continuously drained in the spring to facilitate access. Past and present practices likely influence the soil moisture in the orchid habitat nearby.

Monitoring questions and approach

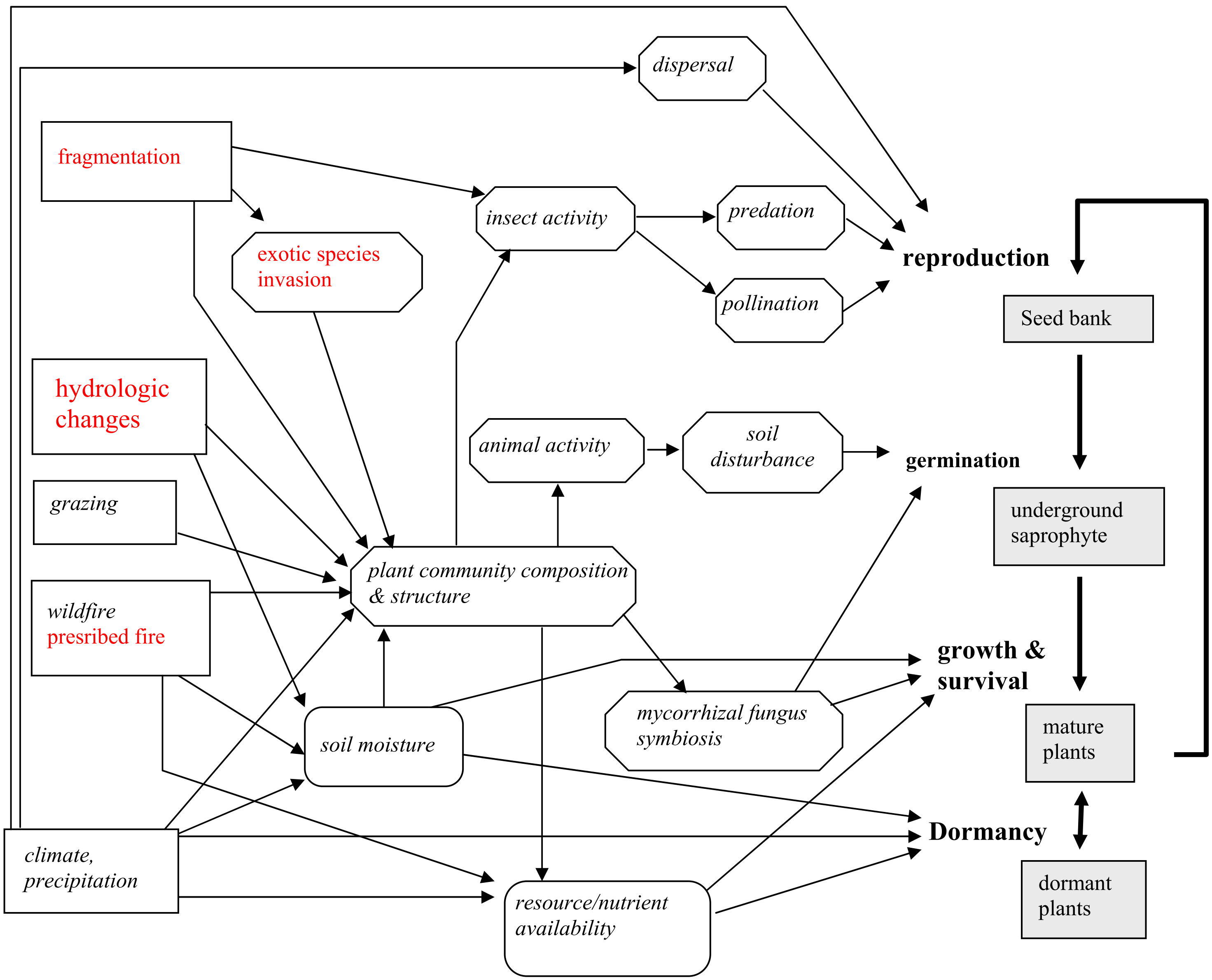
1. How does the abundance and distribution of flowering individuals change over time?
    - Annual census and mapping of flowering individuals.

2. Is the density of non-flowering individuals changing over time?
    - Periodic count of non-flowering individuals in randomly placed plots.
3. Is soil moisture correlated with the abundance and distribution of flowering individuals or the density of non-flowering individuals?
    - Soil moisture is recorded from two sites in the orchid habitat by an automated weather station.
4. How is the tallgrass prairie habitat changing over time?
    - Prairie plant community monitoring is conducted at four sample sites located in native prairie habitat.

Management implications

- Census data helps managers assess whether they are in compliance with the Endangered Species Act.
- Results help clarify the relationship between soil moisture and orchid growth/reproduction. This allows managers to address current and past cultural practices in light of their influence on soil moisture and, indirectly, their effect on orchid persistence.
- Managers must balance an aggressive control program for the invasive grass, smooth brome (*Bromus inermis*) with the potential, harmful side effects to the orchid population (e.g. burning too frequently or post emergence). Monitoring helps managers assess the influence of fire on the density and distribution of orchids and acts as an early warning of any unanticipated deleterious effects.

Figure 12. Conceptual model for western prairie fringed orchid (*Platanthera praeclara*).



8. Black-tailed Prairie Dog (*Cynomys ludovicanus)*

Protocol: Plumb, G. E., G. D. Willson, K. Kalin, K. Shinn, W.M. Rizzo. 2001. Black-tailed prairie dog monitoring protocol for seven prairie parks. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 27 p.

Problem statement and justification

Black-tailed prairie dogs currently occupy less than one percent (700,000 to 800,000 acres) of their historical habitat. The dramatic decline in Black-tailed prairie dog habitat and numbers is the result of changing land use patterns, habitat fragmentation, disease, shooting, and poisoning (U.S. Fish and Wildlife Service 2000). In February 2000 the U.S. Fish and Wildlife Service ruled that the Black-tailed prairie dog warranted listing as a threatened species under the Endangered Species Act of 1973 (National Wildlife Federation 2000a). However, they failed to list the Black-tailed prairie dog as a threatened species because of an overabundance of other higher priority species. The Black-tailed prairie dog is a keystone species; Black-footed ferret (*Mustela nigripes*), Burrowing owl (*Athene cunicularia*), Mountain plover (*Charadrius montana*), Kit fox (*Vulpes velox*), and Ferruginous hawk (*Buteo regalis*) are dependent on them for survival (National Wildlife Federation 2000b). Scotts Bluff National Monument, Nebraska is one of only seven National Park Service units within the historic range of the Black-tailed prairie dog that maintains a population.

Model of key drivers

A conceptual model is presented in Figure 13. Key natural components of the model are as follows:

- Prairie dog grazing influences plant community composition, causing a gradual transition from grassland to areas dominated by annual forbs. Furthermore, on a larger scale, fire and ungulate grazing favorably influence plant community composition for prairie dog colonization. Plant community composition and structure determines the growth, survival and dispersal of prairie dogs.
- A host of bird and mammalian predators influence the survival and dispersal of Black-tailed prairie dogs. In response to heavy predation, the species uses mounded dirt at burrow entrance for look-out points and has an adaptive anti-predator defense call to warn of approaching danger.
- Mortality caused by severe winters, drought, and disease are factors controlling the survival and distribution of the species.

Model components of human origin or under direct human influence are as follows:

- Habitat loss and fragmentation resulting from urbanization and intensive agricultural development negatively influence prairie dog numbers by isolating colonies and exposing them to greater predation, disease, genetic depression, and habitat over-utilization. Moderate grazing, prescribed fire, and chaining are agricultural practices that are beneficial to prairie dogs as they encourage grass production and inhibit invasive woody plants.
- Suppression of wildfires and the introduction of invasive exotic plant species alter the suitability of vegetation for prairie dogs.

- Control of Black-tailed prairie dog numbers through shooting, poisoning, and the use of chemosterilants has greatly reduced their numbers. Most states in the historic range of prairie dogs required landowners to control their numbers in much the same way as noxious plant control programs work.
- Introduction of Sylvatic plague into North America from Europe is believed to cause massive to complete die-off. This becomes increasing true as colonies are reduced in size and become more isolated.

Monitoring questions and approach

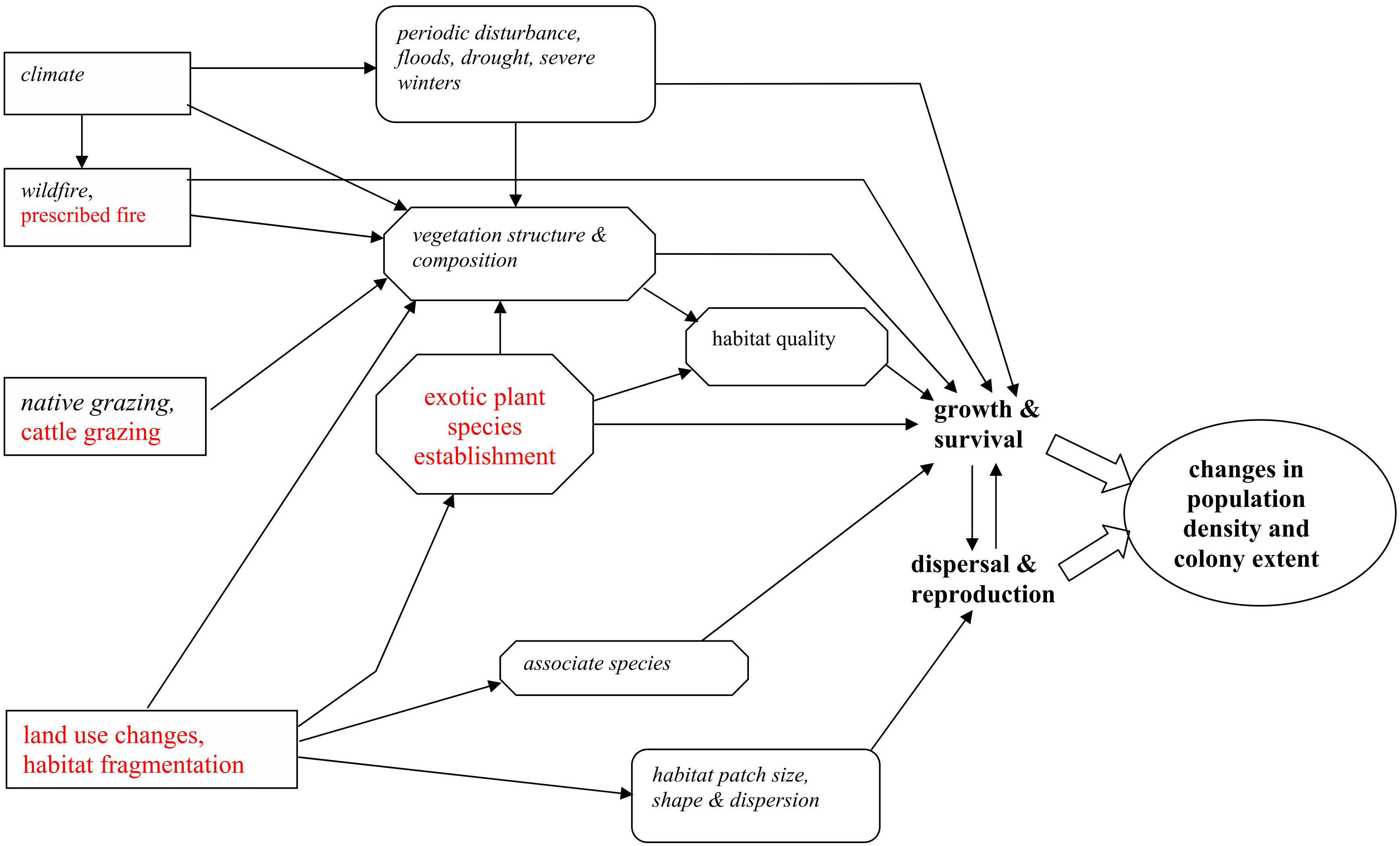
There are three main components to the monitoring of this species:

1. How does abundance fluctuate over time?
   - Annual censuses to track the abundance and trends of the species through time. Visually count all individuals within the colony for three consecutive mornings.
2. How does colony size fluctuate over time?
   - Map the clip line and active burrows to track trends in colony size over time. Use Global Positioning Systems technologies to delineate colony boundaries and size in conjunction with a Geographic Information System.
3. Does Sylvatic plague influence the Black-tailed prairie dog community at Scotts Bluff National Monument.
   - Monitor the Black-tailed prairie dog population for die-offs, document and report all such events to appropriate officials.

Management implications

- Annual surveys help managers assess their effectiveness in conserving prairie dog populations.
- Annual mapping of the clip line and active burrows will warn managers if colony expansion is threatening other park resources.
- Correlation of management practices with annual surveys and mapping data will allow for the mitigation or enhancement of practices influencing population numbers.
- Both annual surveys and habitat monitoring data will contribute to the recovery of the species.

Figure 13. Conceptual model for black-tailed prairie dog (*Cynomys ludovicianus*).



9. Local Climate

Protocol: Akyuz, F.A. and P. Guinan. 2000. Weather monitoring protocol for two prairie parks. . U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 27p.

Problem statement and justification

Two federally listed threatened or endangered plants occur within the Prairie Cluster parks: western prairie fringed orchid (*Platanthera praeclara*) at Pipestone National Monument, and Missouri bladderpod (*Lesquerella filiformis*) at Wilson's Creek National Battlefield. Survival and/or fecundity of both species have been linked to climate conditions. Highly erratic abundance of Missouri bladderpod may in part be related to variable weather conditions and to the interaction of weather and physical site conditions including soil and litter depth in the glade microhabitats (Thomas 1996). Exposed sites with shallow soils are more susceptible to drought and frost heaving, two likely determinants of mortality for Missouri bladderpod. However, under optimal climate conditions, these rocky microhabitats exhibit high rates of survival and fecundity.

Precipitation in the summer of the previous year and during the spring of the monitoring year appears to influence flowering of western prairie fringed orchid. In two low-abundance years (1997 and 1998), precipitation was below normal the previous summer, whereas for one of the peak-abundance years (1996), precipitation the year before was 132% of normal.

Monitoring local weather conditions and microclimate associated with rare plant microhabitats (i.e. soil moisture and soil temperature) may partially explain fluctuations in population dynamics.

Model of key drivers

See Figures 11 and 12.

Monitoring questions and approach

1. How do microclimate conditions vary between microhabitats and among years?

2. Can varying microclimatic conditions be correlated with rare plant population dynamics?

Automated weather stations have been installed adjacent to western prairie fringed orchid habitat at PIPE and within Missouri bladderpod habitat at WICR. In addition to recording standard weather variables, the weather stations will measure soil moisture and soil temperature within different microhabitats.

10. Stream Macroinvertebrates as Indicators of Water Quality

Protocol: Peterson, J.T., W.M. Rizzo, E.D. Schneider, and G.D. Willson. 1999. Macroinvertebrate biomonitoring protocol for four prairie streams. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, Columbia, MO. 46 p.

Problem statement and justification

Urban and agricultural run off, treated sewage, and changes in hydrology all threaten water quality in the small prairie streams of Prairie Cluster parks. Concerns over declining surface water quality have led to the development of many biomonitoring techniques to assess stream water quality (Resh and McElray 1993). Biomonitoring uses living organisms to measure stream water quality along a gradient of conditions from unimpaired (pristine) to severely impacted (heavily polluted and/or disturbed). Aquatic macroinvertebrates are one of the most used groups of organisms in biomonitoing of aquatic systems (Peterson et al. 1999). As such, the National Park Service has implemented macroinvertebrate biomonitoring to track trends in and identify conditions affecting stream water quality.

Model of key drivers

A conceptual model is presented in Part 1, Section B.2. (Figures 5 and 7). Key natural components of the model are as follows:

- The mid-continental biome is shaped by extreme climatic events (e.g. drought, floods). Consequently, prairie streams are characterized by extreme temperature fluctuations, periodic scouring events that limit in-stream nutrient availability and sedimentation, and periods of intermittent flow during drought. Forested reaches have a larger input of nutrients from the terrestrial environment than prairie reaches and a more moderate range of water temperatures.
- Macroinvertebrate community composition depends on water temperature, flow rates, leaf pack availability, and the ratio of riffle to pool habitat within a stream reach.

Model components of human origin or under direct human influence are as follows:

- Urbanization, cattle grazing, poultry/feedlot operations and intensive agricultural development result in sedimentation and eutrophication of streams, which influence prairie stream macroinvertebrate community composition. Species more tolerant of sedimentation and eutrophication replace those species that are less tolerant. Increased daily flow rates of streams resulting from effluent discharge also alter the habitat available to macroinvertebrates.
- Reservoir developments, tributary impoundments, and stream channelizations have all served to reduce the amount and quality of habitat. Reservoirs and impoundments serve as points for sediment deposition. Stream channelization and gravel mining affect macroinvertebrate communities negatively by removing habitat structure, altering stream hydrology, and diminishing water quality.

Monitoring questions and approach

1. What is the status of the stream macroinvertebrate community? What are the long-term trends?
   - Annual sampling to track the abundance and trends of macroinvertebrate species through time. Sampling techniques include Surber sampler for streams with riffle habitat and Hester-Dendy sampler for streams with silted bottoms.
2. What do changes in the macroinvertebrate community indicate about water quality?
   - Analyze species composition, species diversity, tolerance indices, and family abundance ratios to determine water quality.
3. What is the condition of habitat within each stream and how is habitat changing?
   - Habitat data is collected in conjunction with annual macroinvertebrate sampling so that species abundance, locations, and community structure can be tracked over time and correlated with habitat characteristics.
4. Can changes in population status or habitat quality be correlated with management regimes within the watershed?
   - Record management actions for correlation with community structure, habitat data, and estimates of water quality.

Management implications

- Monitoring data from macroinvertebrate communities can be used as an indicator of water quality of streams within park boundaries.
- Correlation of macroinvertebrate data with watershed changes in land use allows for assessment of land use effects on stream water quality within a park. It also allows for assessment of within park management practices on stream water quality.
- Correlation of annual variations in macroinvertebrate data with habitat data allows for a better understanding of the forces driving changes in macroinvertebrate communities.

10. **Topeka Shiner (*Notropis topeka)***

Protocol: Peitz, D.G. In preparation. Long-term monitoring protocol for Topeka shiner (*Notropis topeka*) in National Park Service Units within the Midwest Region, with emphasis on Tallgrass Prairie National Preserve, Kansas and Pipestone National Monument, Minnesota. Prairie Cluster Prototype LTEM Program, National Park Service, Republic, MO.

Problem statement and justification

Knowledge of population dynamics and habitat requirements of the Topeka shiner (*Notropis topeka*), a Federally listed endangered species under the Endangered Species Act of 1973, is limited yet vital to the recovery of the species. National Park Service lands may provide some of the least degraded low order stream habitat remaining in the historic range of the Topeka shiner, and may be critical to recovering the species. Identification and monitoring of National Park Service lands within the historic range of the Topeka shiner where populations exists or habitats are such that re-introduction of the species is viable in accordance with the Topeka Shiner Recovery Plan (U.S. Fish and Wildlife Service, draft) is warranted.

Model of key drivers

A conceptual model is presented in Figure 14. Key natural components of the model are as follows:

- Low order, intermittent streams with clean sand, gravel, and cobble substrates, high water quality, and relatively low water temperatures provide appropriate habitat to support the growth and survival of the Topeka shiner. Stream pools and low water temperatures are maintained by groundwater percolation, as are seasonally flooded off channel habitats. Intense flood events occasionally scour out sediment deposits.
- The Topeka shiner is a diurnal insectivore whose growth and survival depends upon the availability of macroinvertebrates for food. Adult Topeka shiner is preyed upon by predatory fish and birds, while eggs and young may also be preyed upon by predatory macroinvertebrates.
- Habitat quality influences reproductive success. Spawning occurs from late May through July over silt-free sites. It is widely reported that Topeka shiner is an obligate spawner over sunfish nests. However, any silt-free substrate may provide spawning habitat. Males are believed to be territorial over spawning nests.
- Both water temperature and dissolved oxygen concentrations may be limiting factors controlling the distribution of the species.

Model components of human origin or under direct human influence are as follows:

- Urban and agricultural development, cattle grazing and feedlot operations and their associated water pollution, sedimentation and eutrophication are the most critical factors influencing the decline of the Topeka shiner. Irrigation of agricultural lands has also led to habitat destruction by lowering the water table, thus reducing the ability of groundwater to percolate through and maintain off-channel habitats during drought conditions.
- Reservoirs, tributary impoundments, and stream channelizations have all served to reduce the amount of habitat available for the Topeka shiner. Tributary impoundments serve as barriers to downstream migration to more suitable habitats during drought conditions and

to upstream migration for recolonization of stream reaches once drought conditions have abated. Reservoirs can serve as refuges during drought conditions. However, larger native and introduced predatory fish often inhabit these same reservoirs. Reservoirs and impoundments also serve as points for sediment deposition. Stream channelization and gravel mining impact Topeka shiner negatively by removing habitat structure, altering stream hydrology, and diminishing water quality.

- Introduction of exotic species into streams occupied by the Topeka shiner has three potential influences. First, exotics compete directly for food and habitat. Second, some exotics prey on Topeka shiner and their eggs. Third, exotics can introduce disease into waterways occupied by Topeka shiner.

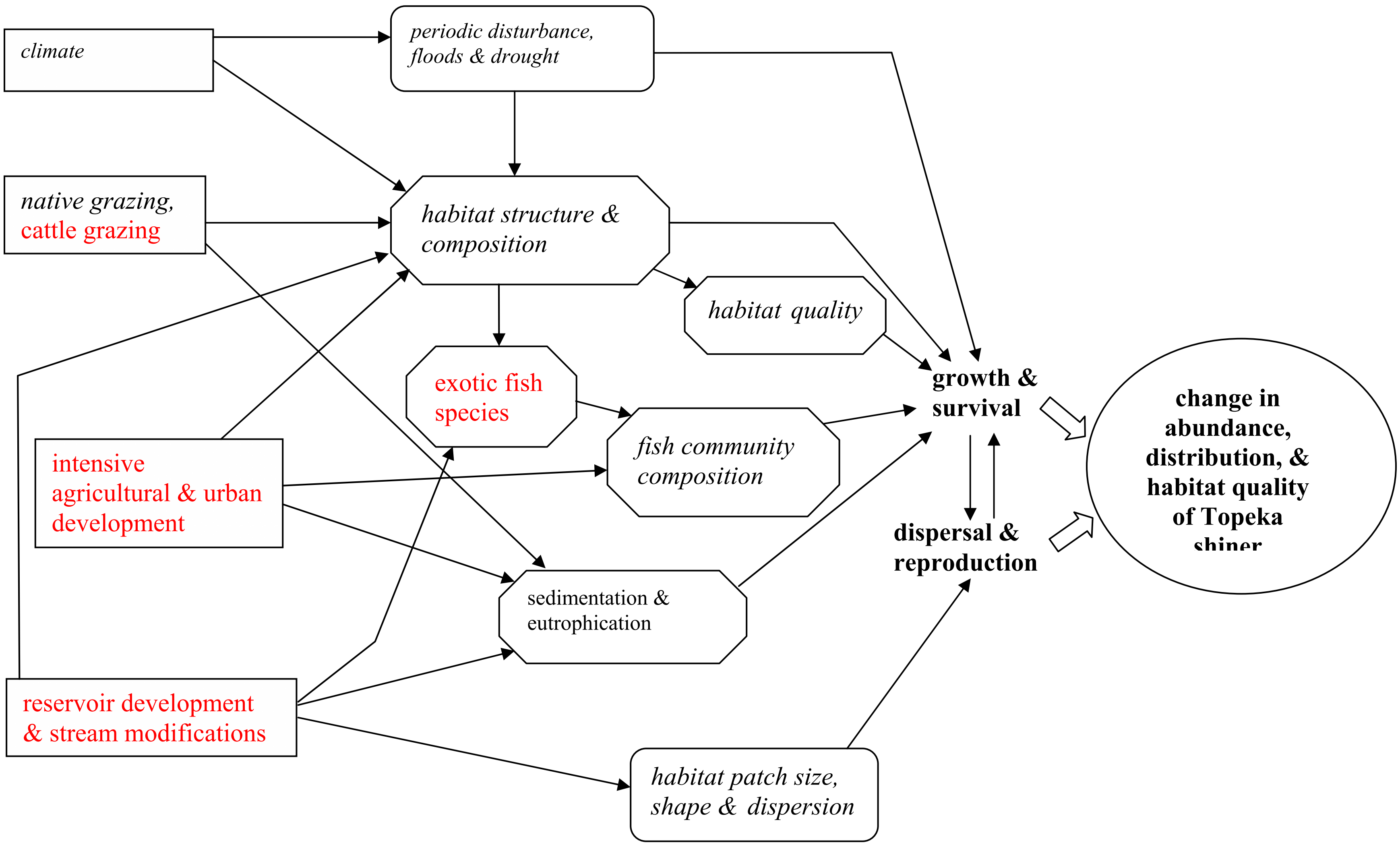
Monitoring questions and approach

1. What is the current status of Topeka shiner populations? What are the long-term trends?
   - Annual censuses to track the location, abundance, and trends of the species through time. Extensive and intensive seining of waterways within park boundaries.
2. Are Topeka shiners reproducing successfully?
   - Annual fall censuses to track the reproductive success of the species.
3. What is the condition of Topeka shiner habitat? How is habitat changing through time?
   - Habitat data is collected during annual abundance censuses so that species abundance and locations can be tracked over time and correlated with habitat characteristics.
   - Identify unoccupied habitat where reintroduction of the species would be viable.
4. Can changes in population status or habitat quality be correlated with management regimes?
   - Record management actions for correlation with population abundance and habitat data.

Management implications

- Annual surveys are important for monitoring long-term trends in populations and habitats and for ensuring the survival of the species.
- Annual surveys may identify habitat for potential reintroduction. The success of any reintroduction attempts within Park Service lands can also be evaluated.
- Correlation of management practices with annual survey and habitat data will allow for the mitigation or enhancement of practices influencing population persistence.

Figure 14. Conceptual model for Topeka shiner (*Notropis topeka*).



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Conceptual Framework, Monitoring Components and Implementation of a NPS Long-Term Ecological Monitoring Program

Prairie Cluster Prototype Program Status Report

Appendix A
Park Descriptions and Maps

Park Description
Agate Fossil Beds National Monument (AGFO)

Agate Fossil Beds National Monument was previously a working cattle ranch owned by Captain James Cook. Established in 1965, the monument preserves paleontological sites considered to be among the world's best deposits of mammalian remains of the Tertiary Age. The park also has historical significance as the summer campsite of the Lakota Sioux leader, Chief Red Cloud, who was a friend to Captain Cook.

Agate Fossil Beds NM is located in the central portion of the northern mixed-grass prairie of the high plains. Two-thirds of the monument's 3,000 acres consist of mixed grass prairie, the most common type being sandreed / sand bluestem prairie. Needle & thread / blue grama prairie occurs on shoulders of flat-topped hills and on eroding sandstone slopes on the sides of hills, while western wheatgrass, willow and cottonwoods are common in the floodplain of the Niobrara River. The Niobrara River, originating 60 miles to the west, provides important habitat for prairie birds and wildlife. Seasonally flooded gravel washes provide habitat for several state listed rare plant species.

Control of Canadian thistle (a noxious weed in NE) is a priority for the park. Managers have used herbicide, bio-controls and mowing to eliminate thistle. Managers are also undertaking restoration of disturbed sites to mixed-grass prairie.

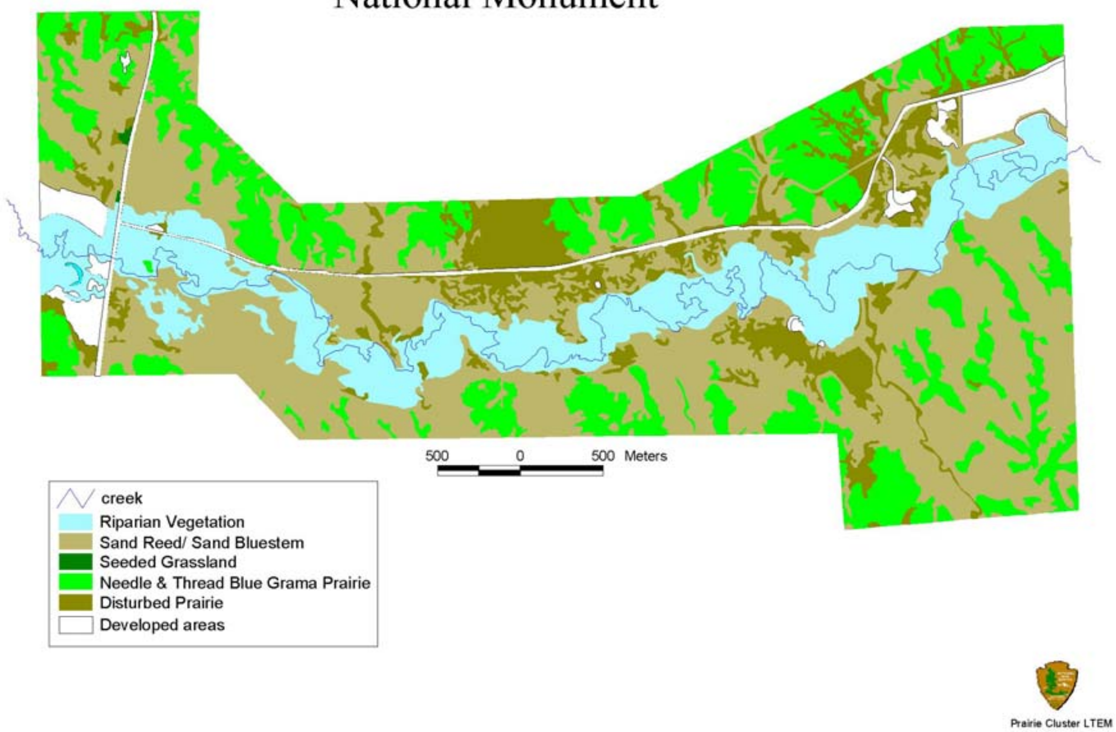
Size: 3055 acres

Habitat types:
sandreed / sand bluestem prairie
needle & thread / blue grama prairie
seeded grasslands
riparian vegetation
Niobrara river

Rare, sensitive habitats:
gravel wash
eroding siltstone slopes

Species of concern:
Smooth goosefoot (*Chenopodium subglabrum*)
Bluff fleabane (*Erigeron ochroleucus*)
Nodding wild buckwheat (*Eriogonum cernuum*)
Leopard lily (*Fritillaria atropurpurea*)
Phacelia (*Phacelia hastata var. hastata*)
Tall northern bog-orchid (*Platanthera hyperborea*)
Smallflower sandverbena (*Tripterocalyx micranthus*)
Swainson's hawk (*Buteo swainsoni*)

Agate Fossil Beds National Monument



Park Description
Effigy Mounds National Monument (EFMO)

Effigy Mounds National Monument was established in 1949 to preserve earth mounds created by the Mound Building Culture of Prehistoric American Indians between 500 BC and 1300 AD. The monument is located in the driftless (non-glaciated) area of northeastern Iowa, and lies in a geologically unique area of erosional topography drained by an intricate system of rivers and streams. The resulting geography includes high divides and precipitous bluffs towering up to 500 feet above adjacent waterways. Cool, north facing, seepy slopes provide habitat for several state rare plant species. Sny Magill, about 11 miles south of the headquarters area, is in the Mississippi River bottom and contains the largest extant concentration of Indian mounds (about 100) in the country

Northeastern Iowa represents an environment of overlapping vegetation zones. Eastern hardwood forests merge with western grasslands to create a mosaic of forests, savannas, and tallgrass prairie. Early land survey records reveal that northeastern Iowa was heavily forested with interspersed oak savannas and tallgrass prairie openings. Along ridge tops, prairie openings penetrated further into the forest, with smaller prairie openings found on south facing bluff edges. Today, 1200 acres of the monument are forested by rapidly maturing stands of mixed hardwood species; approximately 80 acres of old field openings are managed as recovering or restored prairie; and about 100 acres of ponds and lakes are found within the floodplains of the Mississippi River, the Yellow River, and Sny Magill Creek. A hand full of small goat prairies persists on drier bluff top sites.

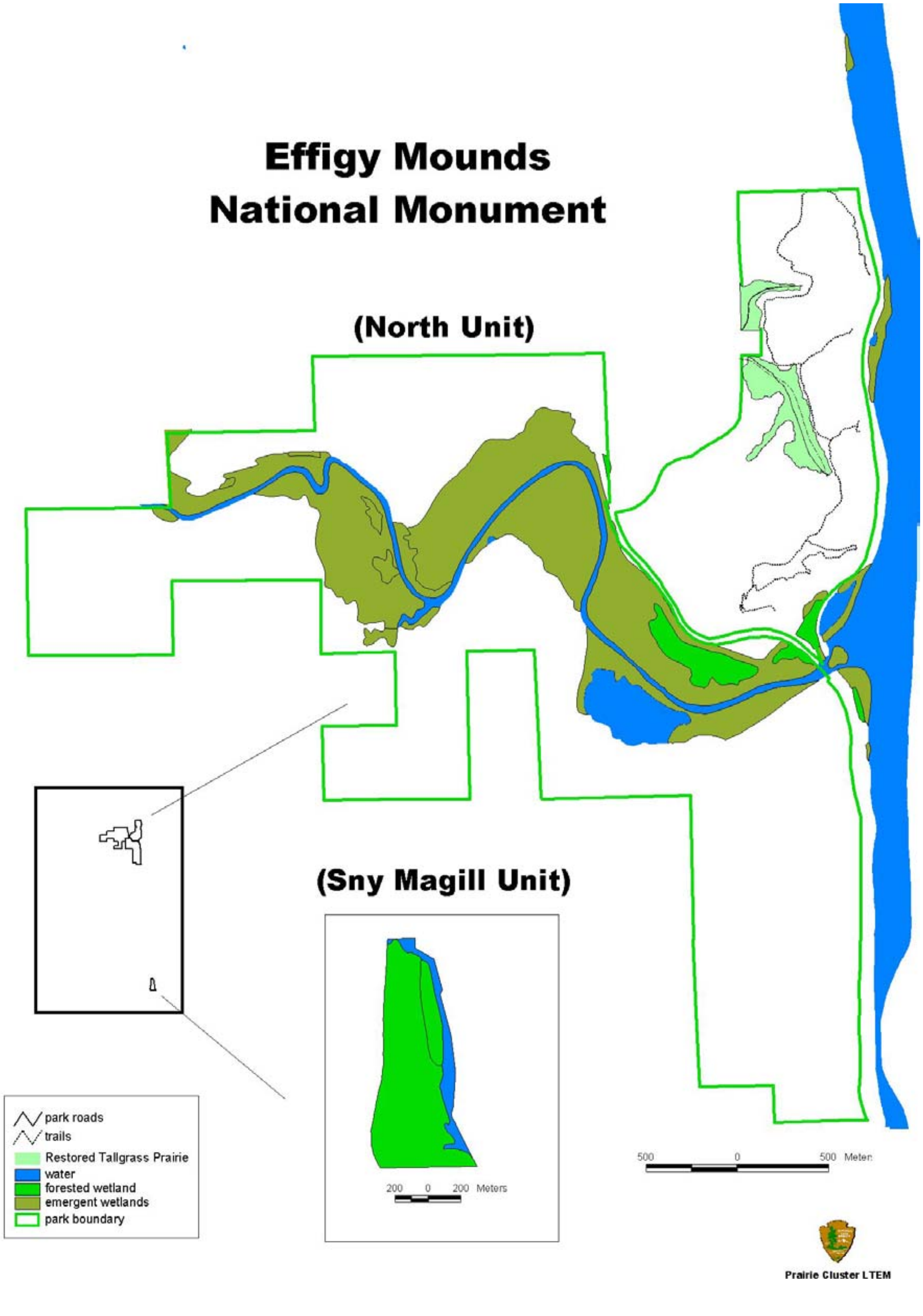
Managers are gradually restoring the cultural landscape; opening savanna sites through prescribed fire and manual thinning. Exotic species, including buckthorn and garlic mustard in the woodlands and smooth brome in the restored prairie, are the focus of control efforts.

Size: 2,493 acres

Habitat types:
bottomland forest
restored tallgrass prairie
wetlands
maple/basswood forest
oak/hickory forest

Rare, sensitive habitats:
goat prairies
bluffs and ledges

Species of concern:
Black bear *(Ursus americanus)*
Red-shouldered hawk *(Buteo lineatus)*
Leathery grape-fern *(Botrychium multifidum)*
Yellow lady slipper *(Cypripedium parviflorum)*
Jeweled shooting-star *(Dodecatheon amethystinum)*
Fancy wood-fern *(Dryopteris intermedia)*
Summer (pigeon) grape *(Vitis aestivalis)*
River otter *(Lutra canadensis)*
Bald eagle *(Haliaeetus leucocephalus)*
Golden corydalis *(Corydalis aurea)*
Water-willow *(Decodon verticillatus)*
American ginseng *(Panax quinquefolis)*
Golden seal (*Hydrastis canadensis)*
Saxifrage *(Sullivantia sullivantii)*


Effigy Mounds
National Monument
(North Unit)
(Sny Magill Unit)
park roads
trails
Restored Tallgrass Prairie
water
forested wetland
emergent wetlands
park boundary
200 0 200 Meters
500 0 500 Meters
Prairie Cluster LTEM

Park Description
Homestead National Monument of America (HOME)

Homestead National Monument of America, was established on the original homestead of Daniel Freeman to commemorate the Homestead Act of 1862 and its effects upon the settlement of the West. When the monument was established in 1936, the upper slopes of the 195-acre site were severely eroded, the lower slopes were covered with heavy silt deposits, and the woodlands were cut over and heavily grazed. In 1939, NPS began restoring prairie vegetation and today the Homestead Prairie represents the second oldest prairie restoration in the Midwest. Plant diversity in the oldest sections of the restored prairie is greater than that of some native remnants in Gage County.

The Monument lies within the glaciated Drift Hill Region of Southeast Nebraska. Bedded limestone and shale underlie the gently rolling topography of the Monument. Today, the vegetation of the Monument is roughly two-thirds restored prairie and one-third woodland, the same general ratio of native prairie/woodland found by the early land surveyors. The Freeman School grounds contain an approximate 0.75-acre remnant of untilled native prairie.

Agricultural, industrial and urban land use adjacent to the park threaten the aquatic and terrestrial natural resources. Exotic plant species and woody shrubs encroach the prairie while herbicide and pesticide run off from farmland degrades the water quality of Cub Creek. Park managers maintain the prairie restoration through prescribed fire, exotic control and removal of woody shrub species.

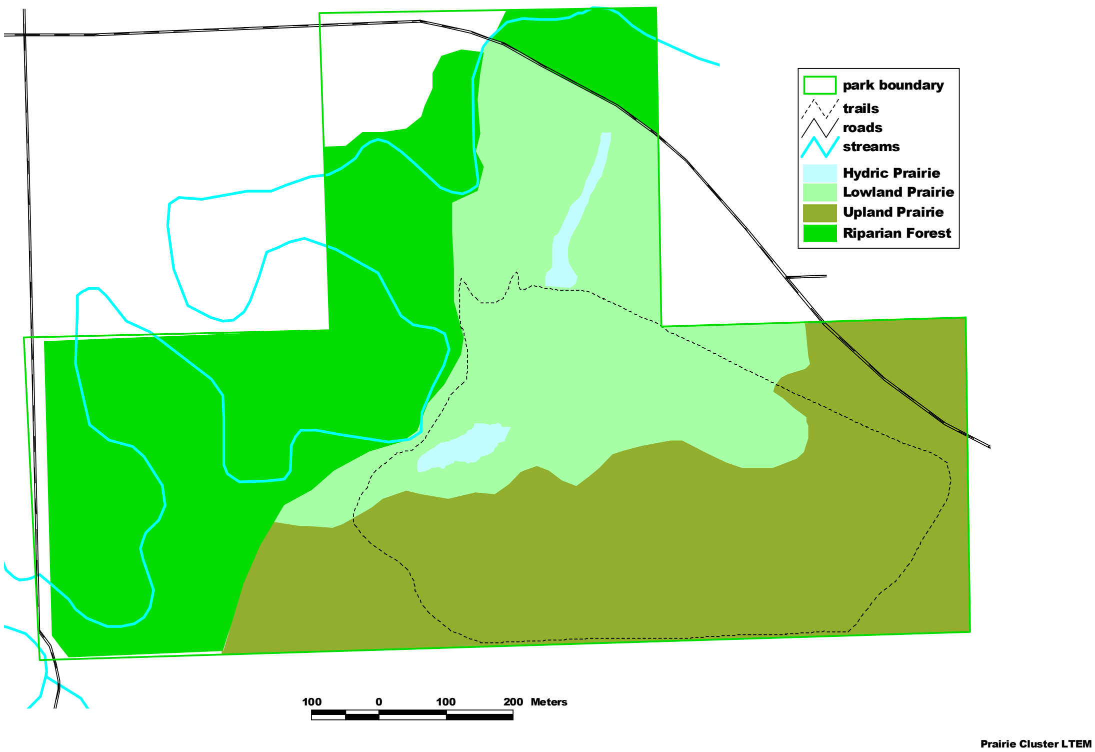
Size: 160 acres

Habitat types:
upland tallgrass prairie
lowland tallgrass prairie
riparian forest

Rare, sensitive habitats:
hydric prairie

Species of Concern:
Regal fritillary (*Speyeria idalia)*

Homestead National Monument of America



Park Description
Pipestone National Monument (PIPE)

Pipestone National Monument was established in 1937 to manage the Catlinite (pipestone) quarries in a way that provides all Native Americans with free access to quarry pipestone. The Monument seeks to preserve and manage the ethnological, historical, archeological, and geological resources in their natural tallgrass prairie environment.

The Monument occupies 283 acres of slightly sloping land in a shallow glacial valley. The vegetation consists of virgin tallgrass prairie, including high-quality and degraded examples. Previous agricultural land (brome pastures) has been restored to native prairie vegetation. The prairie is bisected in a north – south line by a 15-foot high Sioux quartzite outcrop in the eastern quarter and by the pipestone quarry line near the middle of the Monument. A unique plant association, Sioux quartzite prairie, occurs along the outcrop and is considered a significant natural resource to the Monument. Numerous state-listed rare plant species occur in association with the ephemeral pools and dry habitats of the Sioux Quartzite outcrop. The Nature Conservancy has designated this prairie type as "endangered throughout its range", and sites Pipestone as one of the few intact examples of this rare community type. Pipestone creek flows over the Sioux Quartzite outcrop forming Winnewissa Falls.

A population of the federally threatened western prairie fringed orchid (*Platanthera praeclara*) occurs within the high-quality tallgrass prairie. The federally threatened Topeka shiner (*Notropis topeka*) occurs in Pipestone Creek. The challenge to protect these species in a small park is great. Water quality is threatened by herbicide and pesticide runoff from agricultural lands, adjacent urban development, and periodic discharge of toxicants and accidental spillage of contaminants from local industry. Similarly, the native prairie habitat of the orchid is threatened by changes in hydrology and exotic species.

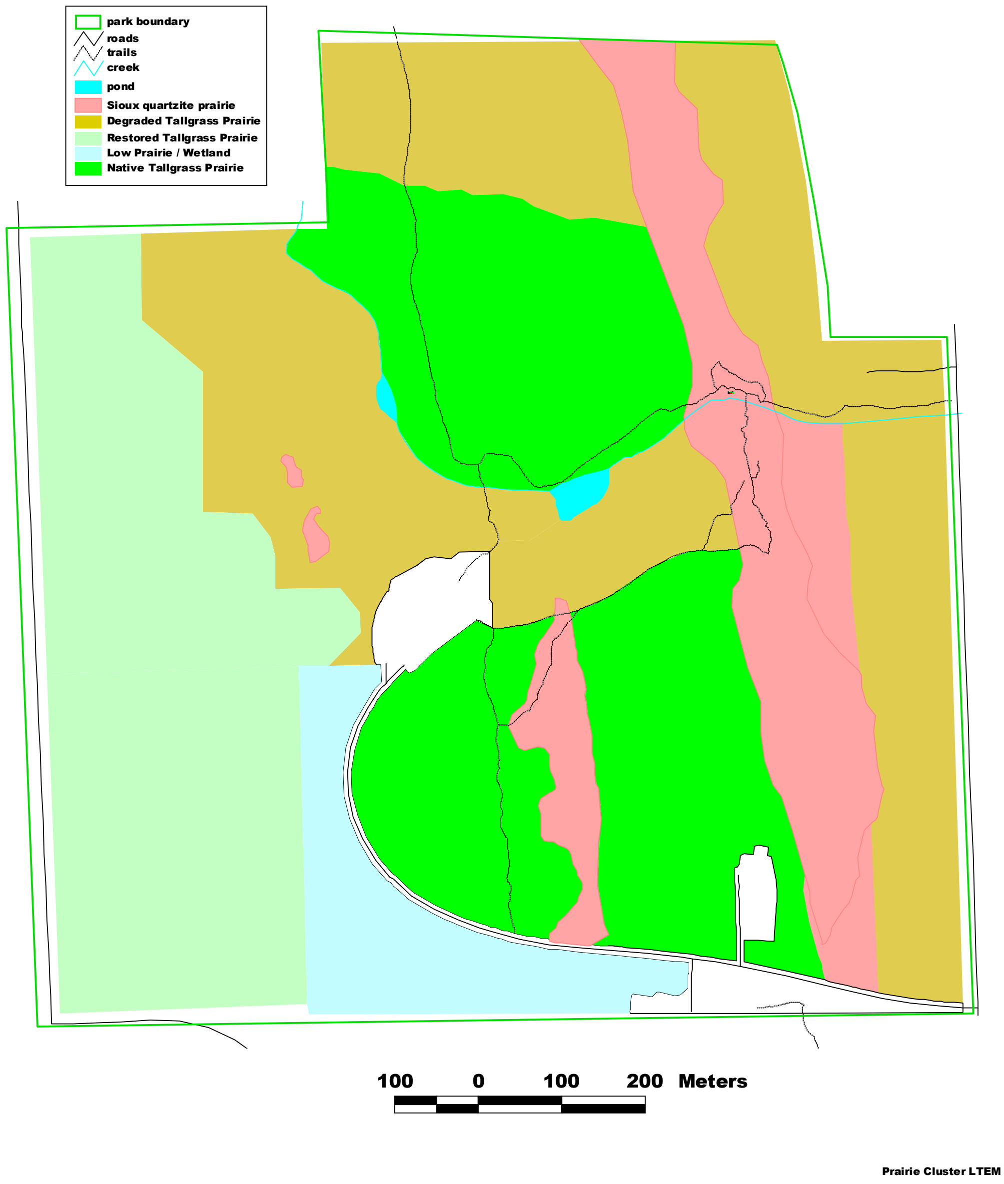
Size: 282 acres

Habitat types:
degraded tallgrass prairie
native tallgrass prairie
Pipestone Creek
restored tallgrass prairie
floodplain/riparian corridor

Rare, sensitive habitats:
low prairie/wetlands
empemeral pools
Sioux quartzite prairie
catlinite quarries

Species of Concern:
Topeka shiner *(Notropis topeka)*
Buffalo-grass *(Buchloe dactyloides)*
Mud plaintain *(Heteranthera limosa)*
Hairy water-clover *(Marsilea vestita)*
Disk waterhyssop *(Bacopa rotundifolia)*
Western prairie fringed orchid *(Platanthera praeclara)*
Sedge *(Cyperus acuminatus)*
Northern mudroot *(Limosella aquatica)*
Longleaf plantain *(Plantago elongata)*
Tumble-grass *(Schedonnardus paniculatus)*
Blackfoot quillwort *(Isoetes melanopoda)*

Pipestone National Monument



Park Description
Scotts Bluff National Monument (SCBL)

The monument was created in 1919 to protect the historic and scientific integrity of Scotts Bluff, a massive promontory that rises nearly 244 m (800 ft) above the North Platte River. The bluff was a significant landmark for westward travelers of the Oregon Trail. The monument's mission directs managers to restore and maintain the native prairie landscape that were seen by the overland emigrants of the 1840's-1870's.

Scotts Bluff NM is located in the central portion of the northern mixed-grass prairie of the high plains. Grasslands at the monument include short and mid-grass prairie communities, the most widespread being needle & thread / threadleaf sedge prairie. Ponderosa pine/rocky mountain juniper woodlands occur in the steep upland draws, while sparsely vegetated, eroded siltstone and sandstone slopes occur at the bluff's base. The arid environment of the slopes provides habitat for several state rare plant species. The monument also supports a colony of black-tailed prairie dogs.

Restoration of disturbed sites to mixed grass prairie began in the early 1970's, with the most recent efforts initiated in 1998. Managers continue to improve their restoration techniques, currently focusing on more effective methods for establishing threadleaf sedge. Managers employ prescribed fire and mowing to control exotic species in the restored and native prairie.

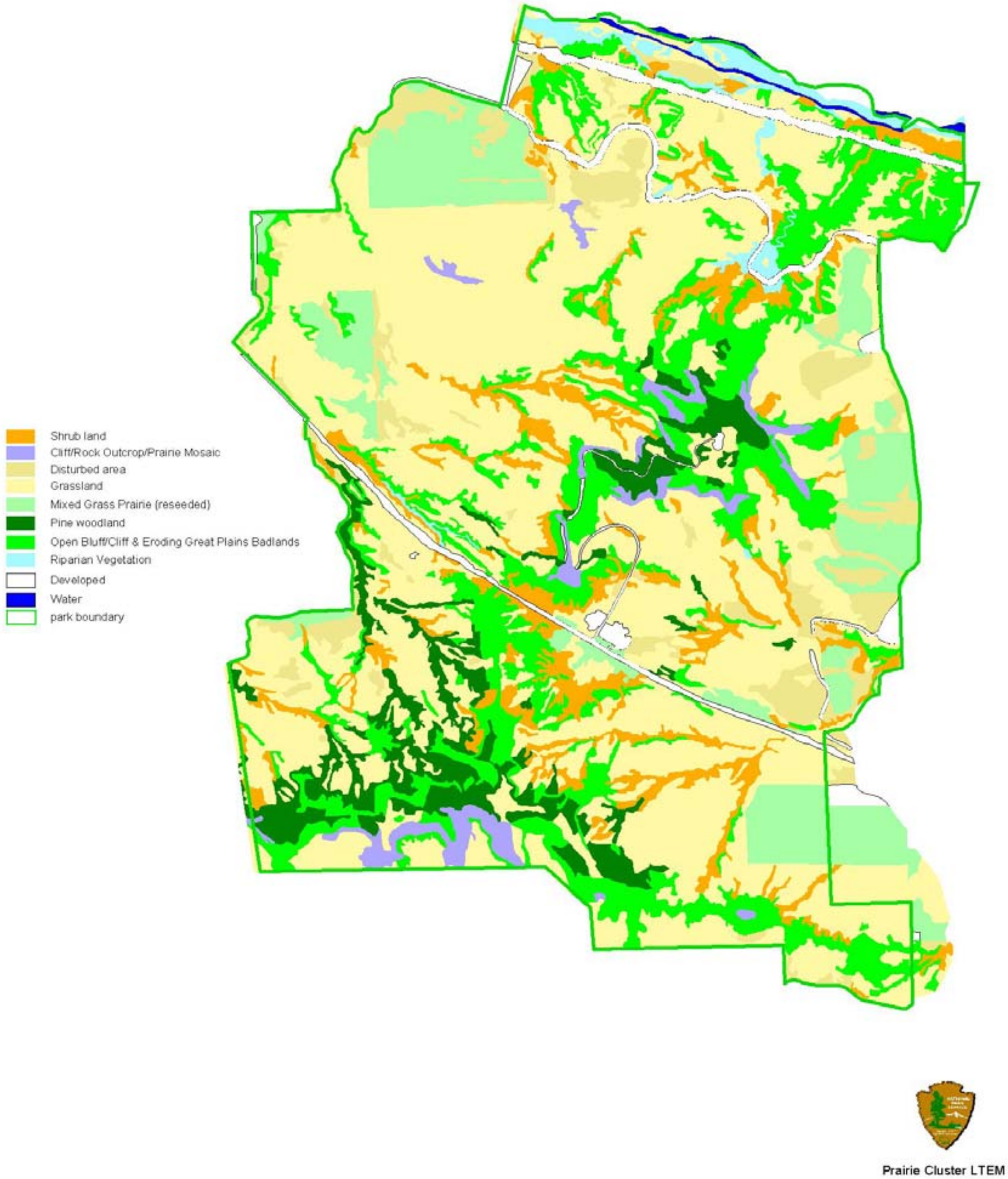
Size: 3000 acres

Habitat types:
shrub land
eroded siltstone/sandstone slopes & bluff
riparian floodplain
mixed-grass prairie
badlands
pine/juniper woodlands

Rare, sensitive habitats:
eroded siltstone/sandstone slopes
badlands
prairie dog town

Species of concern:
Black-tailed prairie dog (*Cynomys ludovicianus*)
Burrowing owl (*Athene cunicularia*)
Platte River milk vetch (*Astragalus pectinatus*)
Polemonium (*Leptodactylon ceaspitosum*)
Skeletonweed (*Stephanomeria runcinata*)
Double bladderpod (*Physaria brassicoides*)
Rabbit brush (*Chrysothamnus parryi* ssp. *Howardii*)
Prairie falcon (*Falco mexicanus*)
Dog parsley (*Lomatium nuttallii*)
Leopard lily (*Fritillaria atropurpurea*)
Stickseed (*Lappula cenchrusoides*)
Phacelia (*Phacelia hastata* var. *hastata*)
Nailwort (*Paronychia sessilifolia*)

Scotts Bluff National Monument



Park Description

Wilson's Creek National Battlefield (WICR)

The park, established in 1960 to preserve and commemorate the Battle of Wilson's Creek, includes approximately 75% of the historic battlegrounds. The Battle is significant as the first major Civil War battle west of the Mississippi River, and as the first battle in which a Union General was killed. The Battlefield retains unusually high integrity relative to other Civil War battlefields.

Wilson's Creek is located within the Springfield Plateau of the Ozark Highlands. In 1861, the site consisted primarily of a pre-settlement landscape of oak savanna, prairie, and limestone glades, with a few farms scattered along the creek. Today, remnants of the limestone glades and oak savanna communities remain on the site, supporting a number of rare plant species, including the federally endangered Missouri bladderpod (*Lesquerella filiformis*). Five caves are located within the Battlefield, totaling approximately 60 feet of undeveloped cave passages. A population of Gray bat (*Myotis grisescens*) has been observed in one cave.

The Battlefield includes approximately 1,100 acres of disturbed land which park staff are restoring to oak savanna or historic fields that were present during the battle. In addition, approximately 500 acres of the park are infested with exotic plant species. The park has active prescribed fire and exotic control programs.

Water resources within the park are being adversely effected by pollution from external sources. The Battlefield lies within a karst area along Wilson's Creek, approximately 2 miles upstream from its confluence with the James River and within the upper portion of the 1,460 square mile James River Watershed. The Battlefield is downstream from the city of Springfield, Missouri (population 140,494) which discharges 42.5 million gallons of treated sewage effluent each day. During low flow periods an estimated 80% of the water flowing through Wilson's Creek National Battlefield is treated sewage effluent.

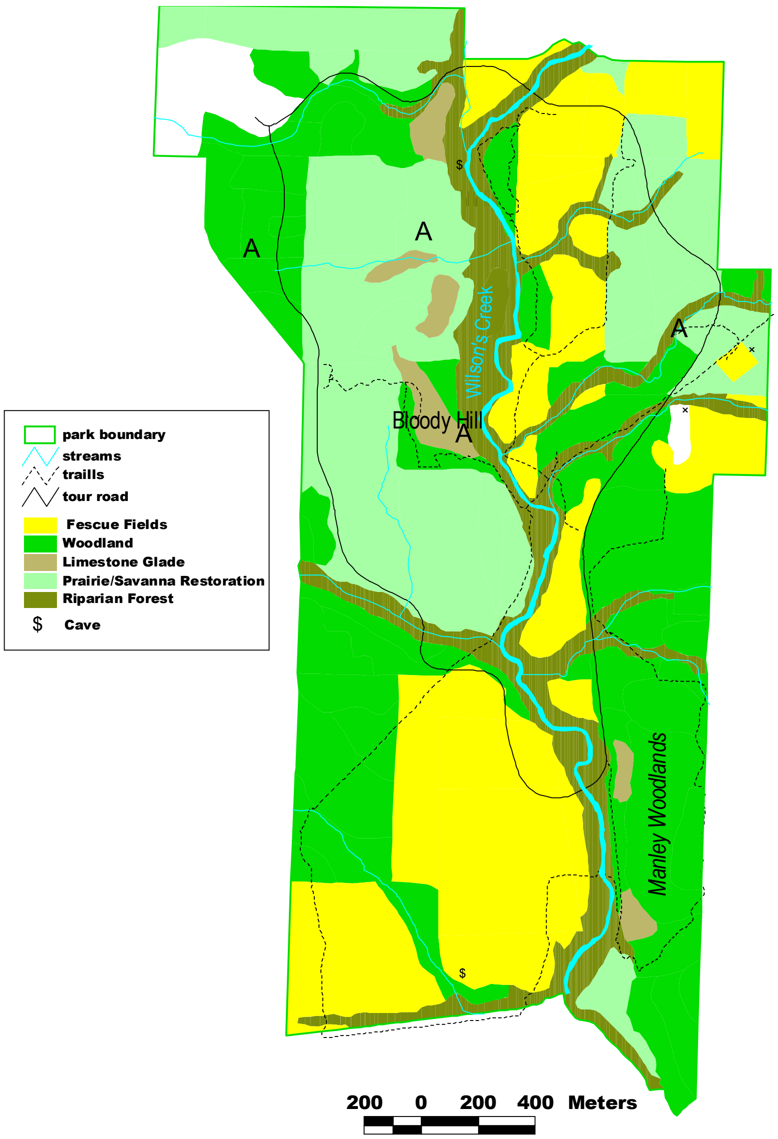
Size: 1,750 acres

Habitat types:
oak woodland
fescue fields
Wilson's Creek
riparian forest
restored prairie/savanna

Rare, sensitive habitats:
limestone glade
seeps/springs
rock ledge/bluff

Species of concern:
Missouri bladderpod *(Lesquerella filiformis)*
Buffalo-grass (*Buchloe dactyloides*)
Royal catchfly (*Silene regia*)
Blue grama grass (*Bouteloua gracilis*)
Gray bat *(Myotis grisescens)*
Mallow (*Malvastrum hispidum*)
Greenthread (*Thelesperma filifolium*)

Wilson's Creek National Battlefield



Prairie Cluster LTEM